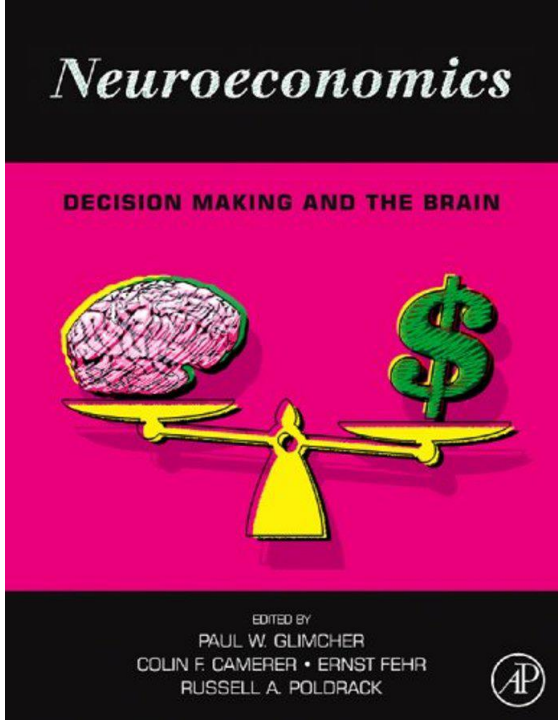
Neuroeconomics

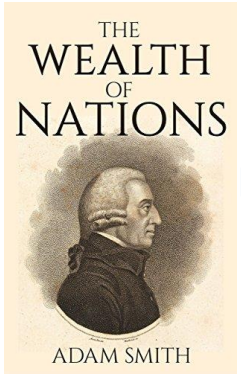
How our brain decides



Summary

- **Introduction: A Brief History of Neuroeconomics**
- Methods used to study decision making
- Low level decision making
- High level decision making

Conceptual map



History

- Allais Paradox
  - **Lack of rationality**
  - **We are social animals**
- Asian Disease

Study DECISION MAKING using psychology and neuroscience:

1) Options
2) Not random decisions
3) Goal-directed

Inferior parietal lobe

Lateral intraparietal area

→ **Low level decisions: Perceptual Decisions and Motion Decisions**

Memory, Probability, Value/Utility, Emotions →

Orbitofrontal cortex → options

Ventrolateral cortex → selfcontrol

DLPFC → planning and organization

aCC → learning consequences

→ **High level decisions**

METHODS of neuroeconomic and decision making

Electrical stimulation

Lesions

TMS

Single-cell recordings

EEG and MEG

fMRI

Summary

- **Introduction: A Brief History of Neuroeconomics**
- Methods used to study decision making
- Low level decision making
- High level decision making

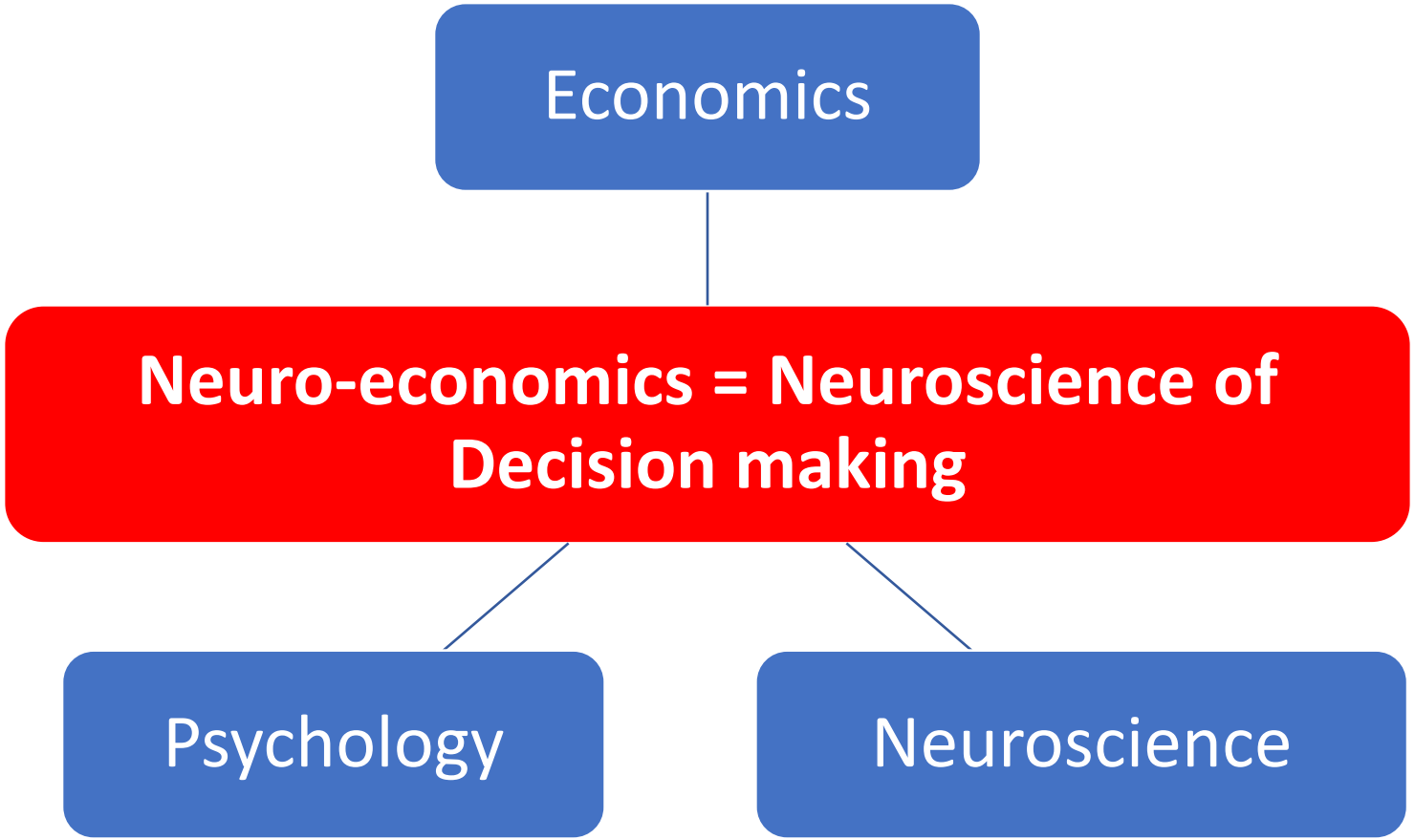
Introduction

- Neuroeconomics is an **interdisciplinary field**

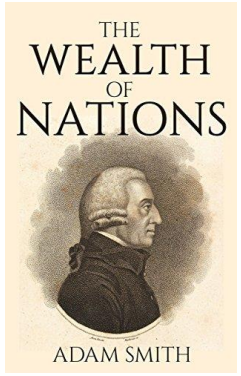
- **Aim:** to explain (using specific technique) human decision making, e.g. our ability to chose among multiple alternatives.

- It studies how economic and decision making behaviors are written in our brain.

Neuroeconomics as interdisciplinary field



Evolution of economic



Classical period of economic theory

- In order to understand the evolution of neuroeconomics we have to go back to the **evolution of economic**
- The birth of economic is often traced to Adam Smith's publication of The Wealth of Nations in 1776. Smith described a number of phenomena critical for understanding choice behavior (e.g. how characteristics of the environment influenced the behavior of consumers and producers).

Basic concepts:

- Introduction of different concepts:
  - Value
  - Price
  - Cost

- wealth of any nation was determined by national income (and not monarch's gold!!),
- Income is based on the labor
- Labor organized efficiently by the division of labor
- **Theory of value (of exchange)**

Evolution of economic

- **Price** is the amount paid for acquiring any product or service.
    - Market price vs Natural price (gravitational attraction)

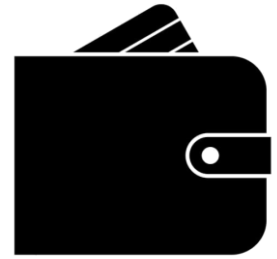
- **Cost** is the amount incurred in producing and maintaining the product.

- **Value** is the utility of a good or service for a customer.

PRICE

- Price is the consideration given in return for acquiring a good or service. In a commercial transaction, price refers **to the amount charged** by the seller from the buyer, in exchange for any product or service, which includes cost and profit.
- It is referred by different names in different contexts:
  - **Fees**: For the supply of professional services.
  - **Premium**: In the case of insurance.
  - **Rent**: For the use of place or machinery.
  - **Fare**: In the case of transportation.
  - **Salary**: For the work done in an organization.

COST



- The cost can be defined as the total amount spent on the inputs like land, labour, capital, machinery, material, etc. with an aim of producing the product or supplying the services. It can be anything which adds to the expense of product or service manufactured or supplied by the firm.
- In simple terms, cost implies the financial worth of the sacrifice made, to obtain the goods or services. It is incurred for present or future benefits. The basic elements of cost are: **Material, Labour and Overheads**.

Value

- Value can be described as the benefit derived by the customer from the product or service. In clearer terms, value is what a customer perceives the product or service is worth to them.
- Characteristics:
  1. *Immeasurable in nature. because the value of the product is different for different persons.* 
  2. *Value varies from time to time.* 
  3. *Value of a product or service greatly depends on the supply of the product and the demand among the buyers. (e.g. if the supply is less → demand more → more value)*
  4. *Differs from one place to another.*

Evolution of economy

Neoclassic revolution

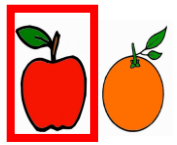
After this classical period, **different competing schools appeared**

Neoclassical

Different schools

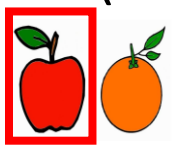
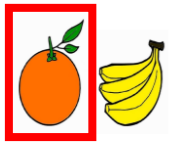
Samuelson → **mathematical structure of consumer choice** and behavior in markets

- WARP (*Weak Axiom of Revealed Preferences*)

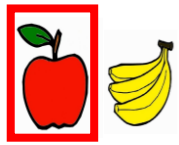


CHOICE reveals a PREFERENCE

- GARP (*Generalized*)

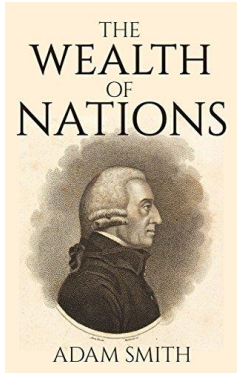



indirectly



Edgeworth, Ramsey, Fisher →hedonimeter (tool to infer value from physical signals)

Evolution of economy



Classical period of economic theory → **Neoclassical**

CONSUMER BEHAVES:

- Using **UTILITY FUNCTION: that relates the subjective value with the objective value**
- To Maximize Utility

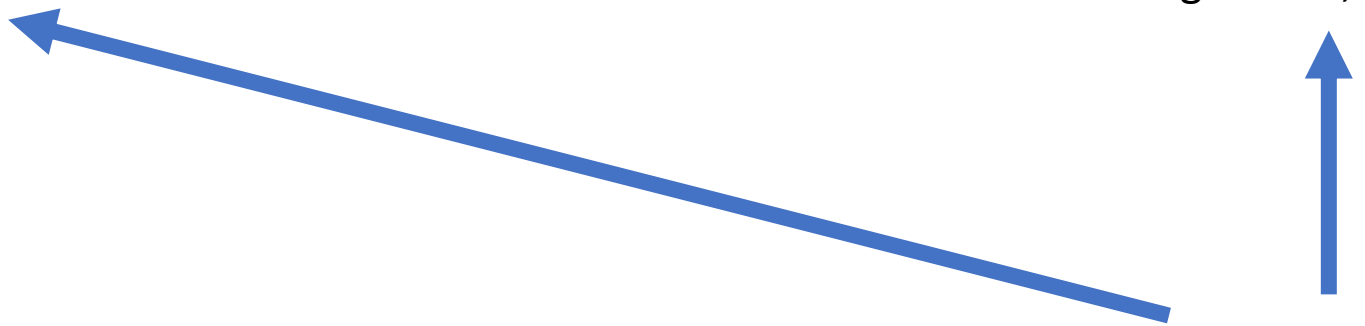
PROBLEMS ←

At the end of this period, neoclassical economics seemed incredibly powerful. However different problems emerged

Evolution of economy

Famous experiment conducted by **Tversky and Kahneman** (1981).

Allais paradox (1953):
The **Allais paradox** arises when comparing participants' choices in two different experiments, each of which consists of a choice between two gambles, A and B.



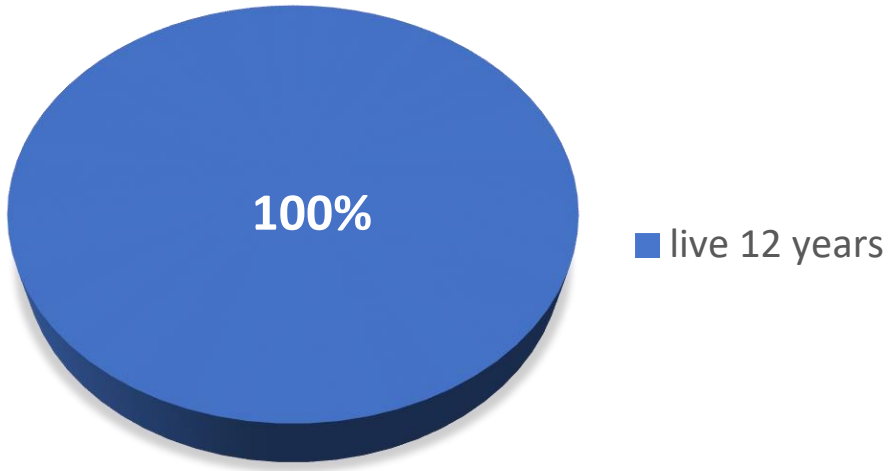
Neoclassical vs **behavioral economics**

Human beings are not rational animals. Different economic behaviors are not fully explained by these models (e.g. heuristics)

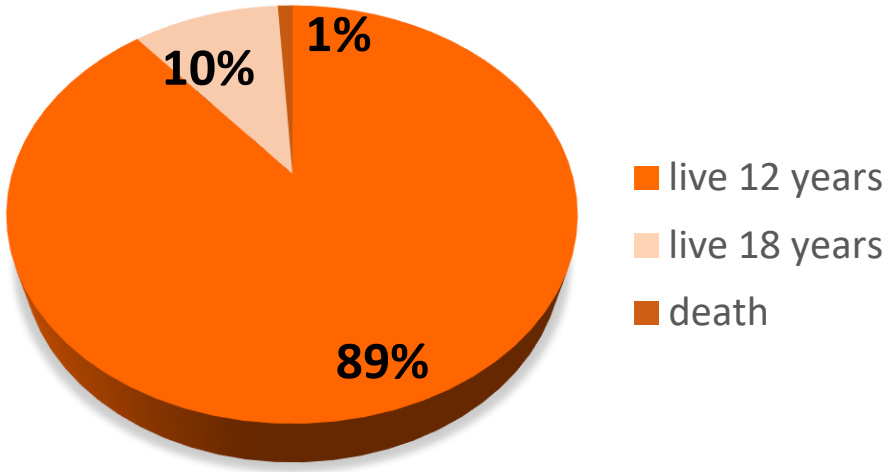
Behavioral economics: This group of psychologists and economists, who began to call themselves behavioral economists, argued that evidence and ideas from psychology could improve the model of human behavior inherited from neoclassical economics

Allais paradox

100% chance of living 12 years before dying



89% chance of living 12 years before dying
10% chance of living 18 years
1% chance of sudden death

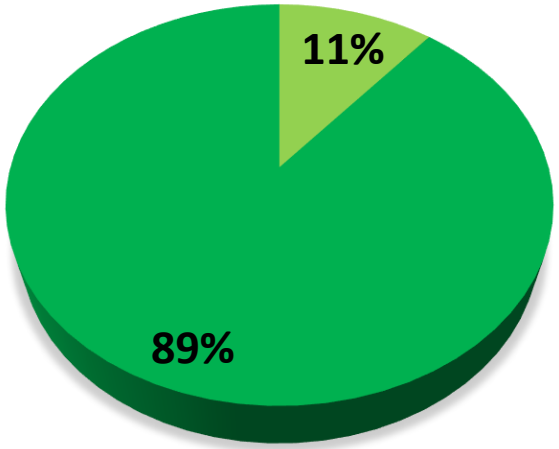


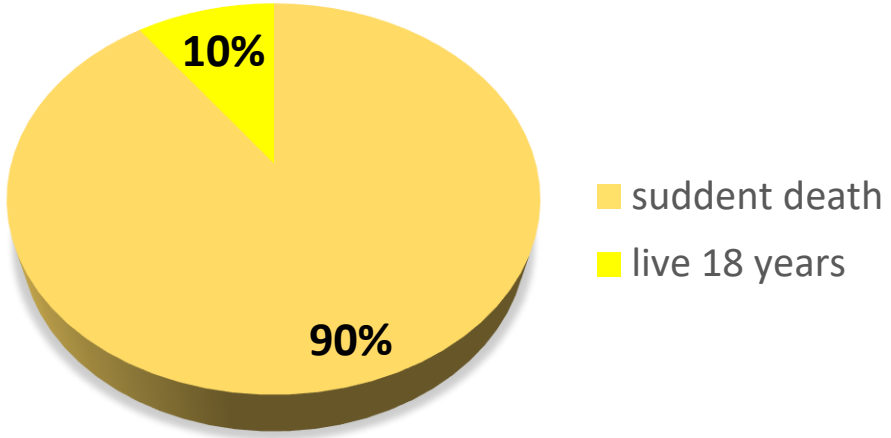
WHICH DO YOU CHOOSE?

Allais paradox: different scenario

11% chance of living 12 years
89% chance of sudden death

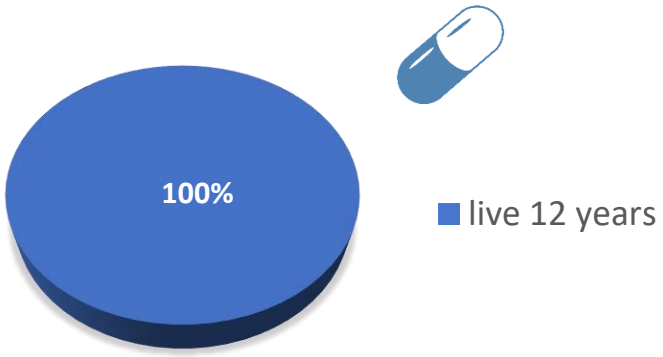
90% chance of sudden death
10% chance of living 18 years

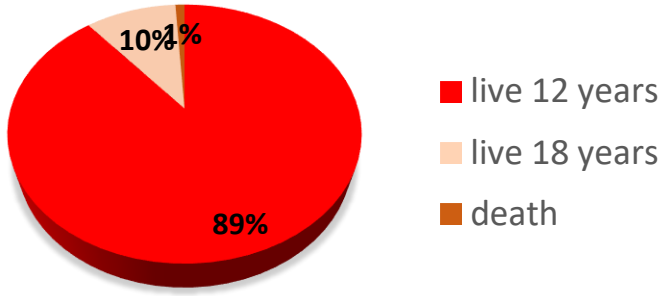


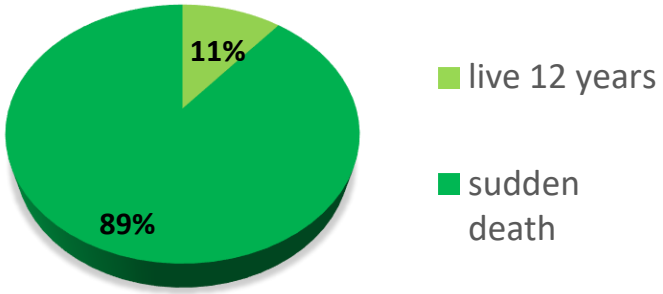


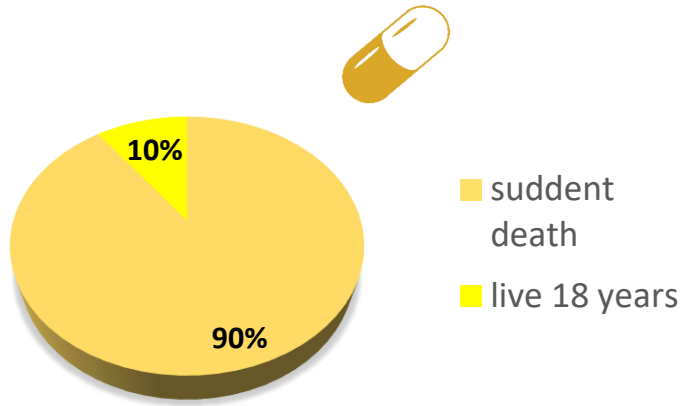
WHICH DO YOU CHOOSE?

Results

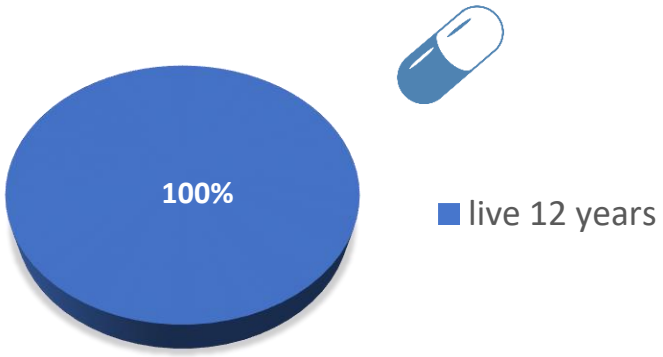

100%
live 12 years

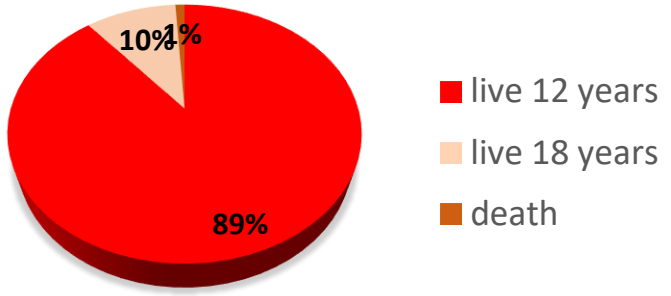

10%
1%
89%
live 12 years
live 18 years
death


11%
89%
live 12 years
sudden death

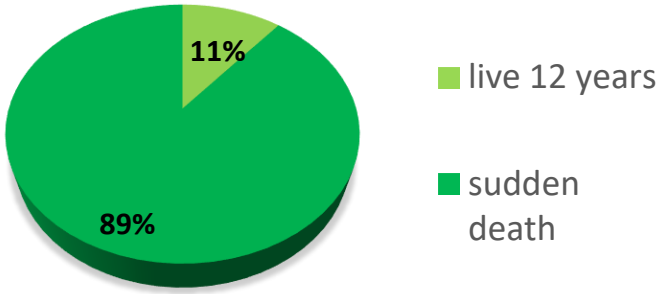

10%
90%
suddent death
live 18 years

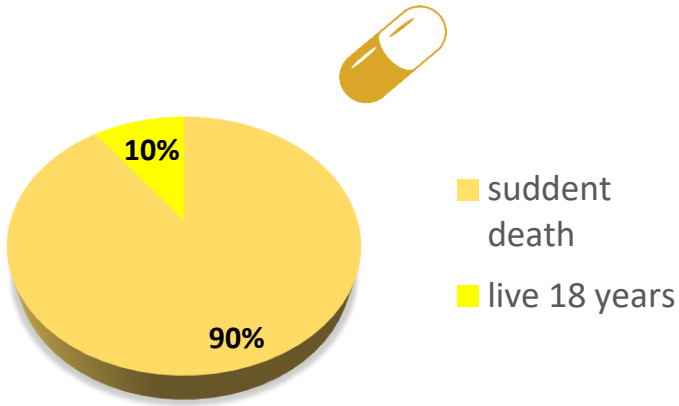
Results



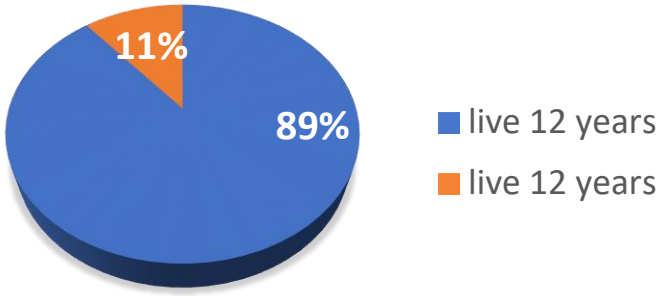


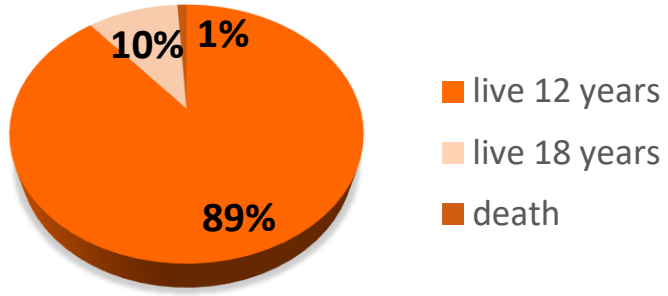
These options have the same outcome 89% of the times!!

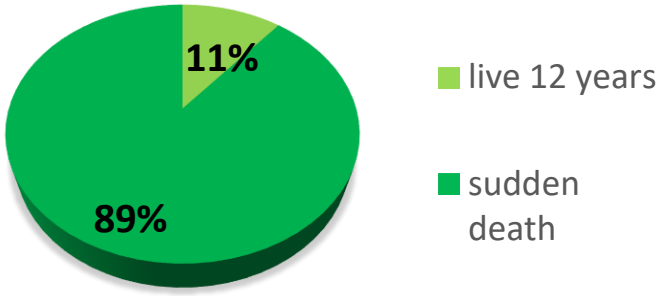


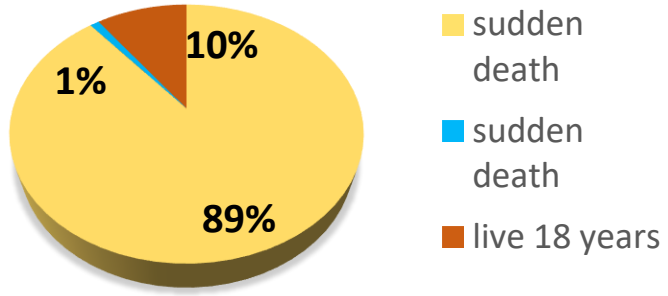


What if we write the options in a different way









Conclusions

- We tend to make decisions based on how much we think we have to gain or lose **right now**

- We also tend to choose **certainty** over risk, even riskier options are closer to what we really want.

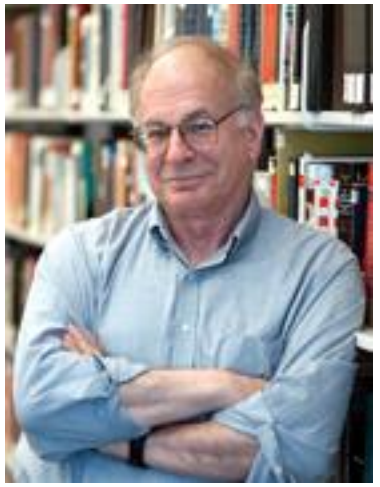
- Sometimes we consider the **probability**, other times the **value** of the option.

Asian disease example → lack of rationality in our decision making

- Famous experiment conducted by Tversky and Kahneman (1981)

- Participants were asked to "imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to fight the disease have been proposed. Assume the exact scientific estimate of the consequences of the programs are as follows."
- 2 groups of participants

Amos Nathan Tversky, 1937-1996



Daniel Kahneman, 1934

Asian disease example → lack of rationality in our decision making

Participants were presented with a choice between 2 programs.

GROUP 1

In a group of 600 people:

•Program A: "200 people will be saved“

•Program B: "there is a 1/3 probability that 600 people will be saved, and a 2/3 probability that no people will be saved"

So, which program would you select?

Asian disease example → lack of rationality in our decision making

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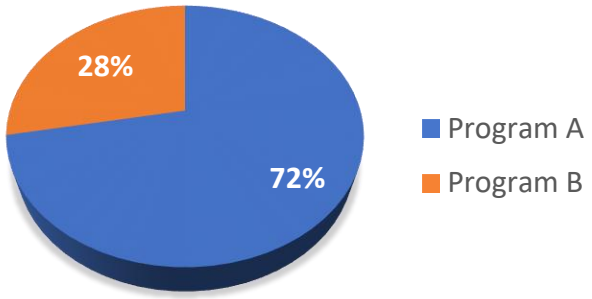

Asian disease example → lack of rationality in our decision making

Participants were presented with a choice between 2 programs.

GROUP 2

In a group of 600 people:

•Program C: "400 people will die“

•Program D: "there is a 1/3 probability that nobody will die, and a 2/3 probability that 600 people will die"

So, which program would you select?

Asian disease example → lack of rationality in our decision making

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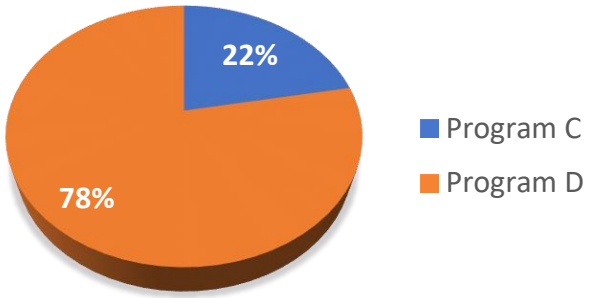

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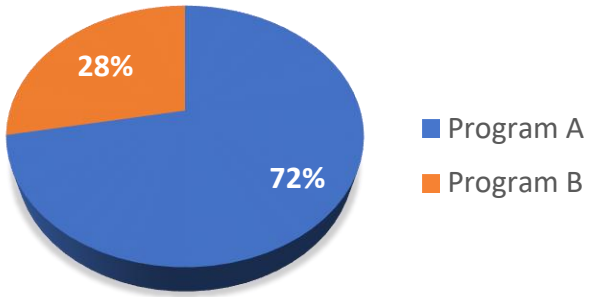


Identical programs but “framed” in a different domain

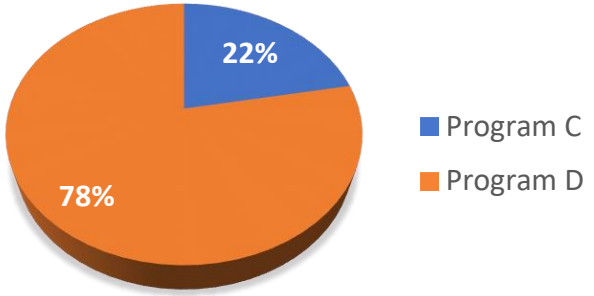
Gain domain vs Loss domain

GROUP 2

In a group of 600 people:

•Program C: "400 people **will die**“

•**Program D**: "there is a 1/3 probability that nobody will die, and a 2/3 probability that 600 people will die"



Asian disease example → lack of rationality in our decision making

Conclusion: framing of the options can change our decisions

1. Are we rational?

2. Are we consistent in our decision processing?

The answerer is no.

We can use **psychology** to address this issue.

Neuroeconomics as interdisciplinary field

Economics

Rationality problem

Psychology

Psychology

- Psychologists question our rational behaviour

- *We are irrational and we are social*

Kenning & Plassmann, Brain Research Bulletin 67 (2005), 343–354

Social psychologists question our behaviour as individuals

We are “social” animals…

1. We need to investigate human behavior in social conditions (e.g. Ultimatum game, or trust game)
2. We need to investigate not only behavioural variables but also objective measures

Game theory to study “social” individuals' decision making

- Game theory provides a nice middle ground for neuroeconomic studies, because it links individual decision making to group-level outcomes with a clearly defined mechanism.
- The mechanism is the game tree, which specifies who gets to move, when, what moves they can make, what information they have when they make their move, and how moves of different players interact to determine a joint outcome over which the players have varied interests.

Game theory to study “social” individuals' decision making

- An important feature of laboratory game theory experiments is that **participant’s decisions can be highly sensitive to the specifics of the implementation**.

- Many game theory experiments are powerful tools for uncovering critical features of the human decision process that might be relatively difficult to detect outside of controlled environments

Characteristics of game theory experiments

- Instructions need to be clear and complete.
- Environment needs to be well described and framed since behavior is highly sensitive to framing.
  - E.g. using the word “ partner ” instead of “ counterpart ” to describe a matched participant in an experiment can affect decisions substantially

Houser et al ., 2004

Characteristics of game theory experiments

- The role of **randomization** also cannot be overstated. One reason is that it is necessary for the validity of a variety of widely-used analysis procedures.
- More generally, the appropriate use of randomization avoids confounding influences on the results.
- Subjects might differ in personality traits or preferences for money
- Random assignment of subjects to treatments and roles within the experiment helps to ensure that such differences do not systematically affect an experiment's outcome.

Houser et al ., 2008

Characteristics of game theory experiments

- To guarantee **anonymity**, participants are randomly assigned counterparts, visually separated from each other, and asked to remain silent for the duration of the experiment.
- By ensuring that participants do not know with whom they are matched, the possibility that decisions will be based on perceptions unrelated to the decision environment under study is largely eliminated.

Characteristics of game theory experiments

- A hallmark of experimental economics is “**salient rewards**”.
- Salient rewards refer to monetary payments that vary according to a person’s decisions in an experiment.
- Vernon Smith formalized the importance of this procedure with the publication of his “Induced Value Theory” (Smith, 1976). As long as it is assumed that people prefer more money to less, applying the theory to experiments requires only that **real money values are assigned to tokens earned in an experiment**.
- Intuitively, the advantage of doing this is that it raises confidence that participants will recognize the **economic incentives** implied by the game environment.

Examples of game theory experiments

Prisoner’s Dilemma

- Prisoner’s dilemma game is used to study “ social dilemmas ” that arise when the welfare of a group conflicts with the narrow self-interest of each individual group member

Ultimatum Games

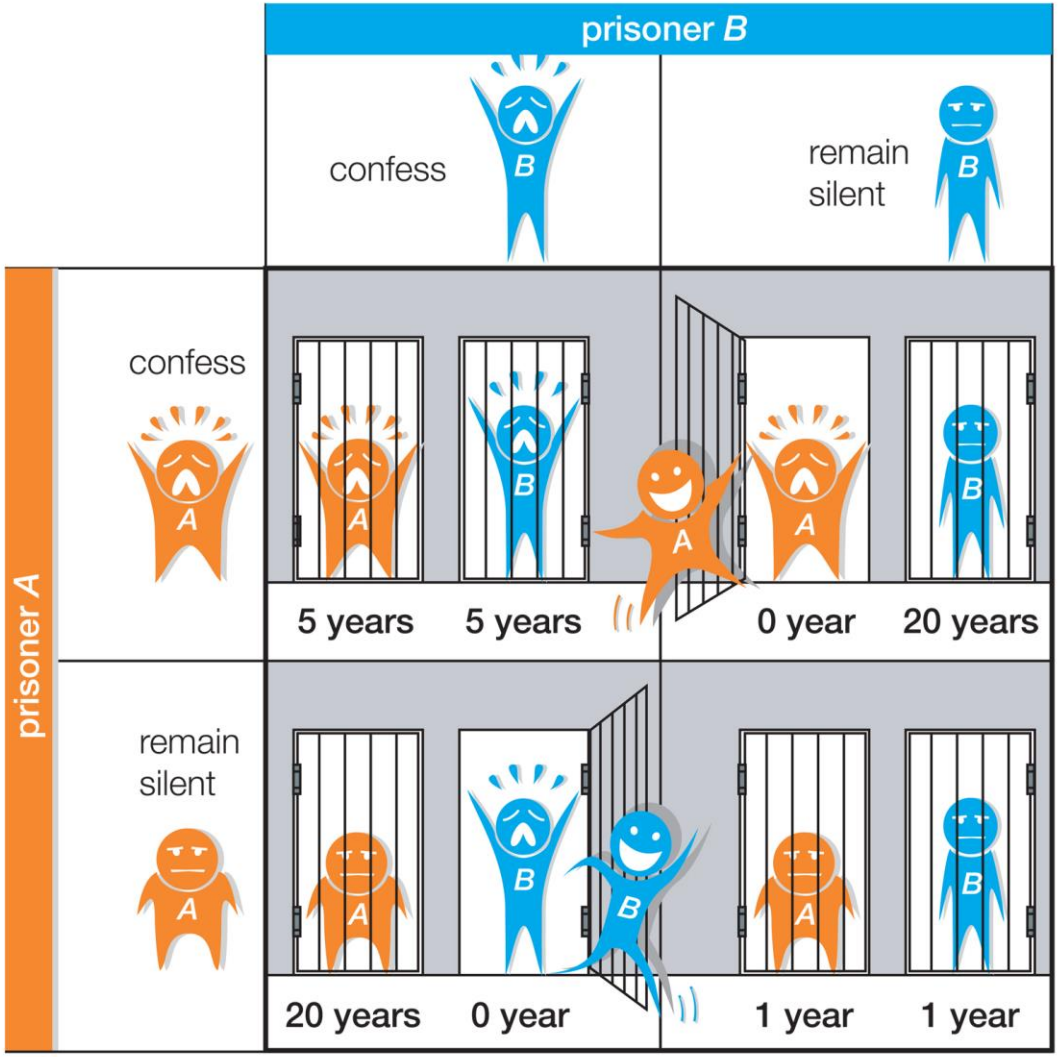
- The ultimatum game, introduced by Guth et al. (1982), is a simple take-it-or-leave-it bargaining environment.

Prisoner's Dilemma (PD) Games

- In a typical two-player PD, each player can choose either to "cooperate" or "defect".
- Payoffs are symmetric and chosen so that the sum of the payoffs is **HIGH** when both choose "cooperate" and **LOW** when both players choose "defect".
- However, **each player earns the most if he chooses to "defect" when the other cooperates**.

- The structure of multi-player PG games is similar, but they are typically played in larger groups.

Prisoner's Dilemma (PD) Games



Prisoner's Dilemma Games results

- Standard results for PD games are highly discussed in different papers (see, for example, Davis and Holt, 1993; Ledyard, 1995).

- The key early finding was that, in aggregate, **cooperation occurs about half of the time in PD game**.

- It is also routinely found that aggregate cooperation **decays when these games are repeated**.

Ultimatum Games

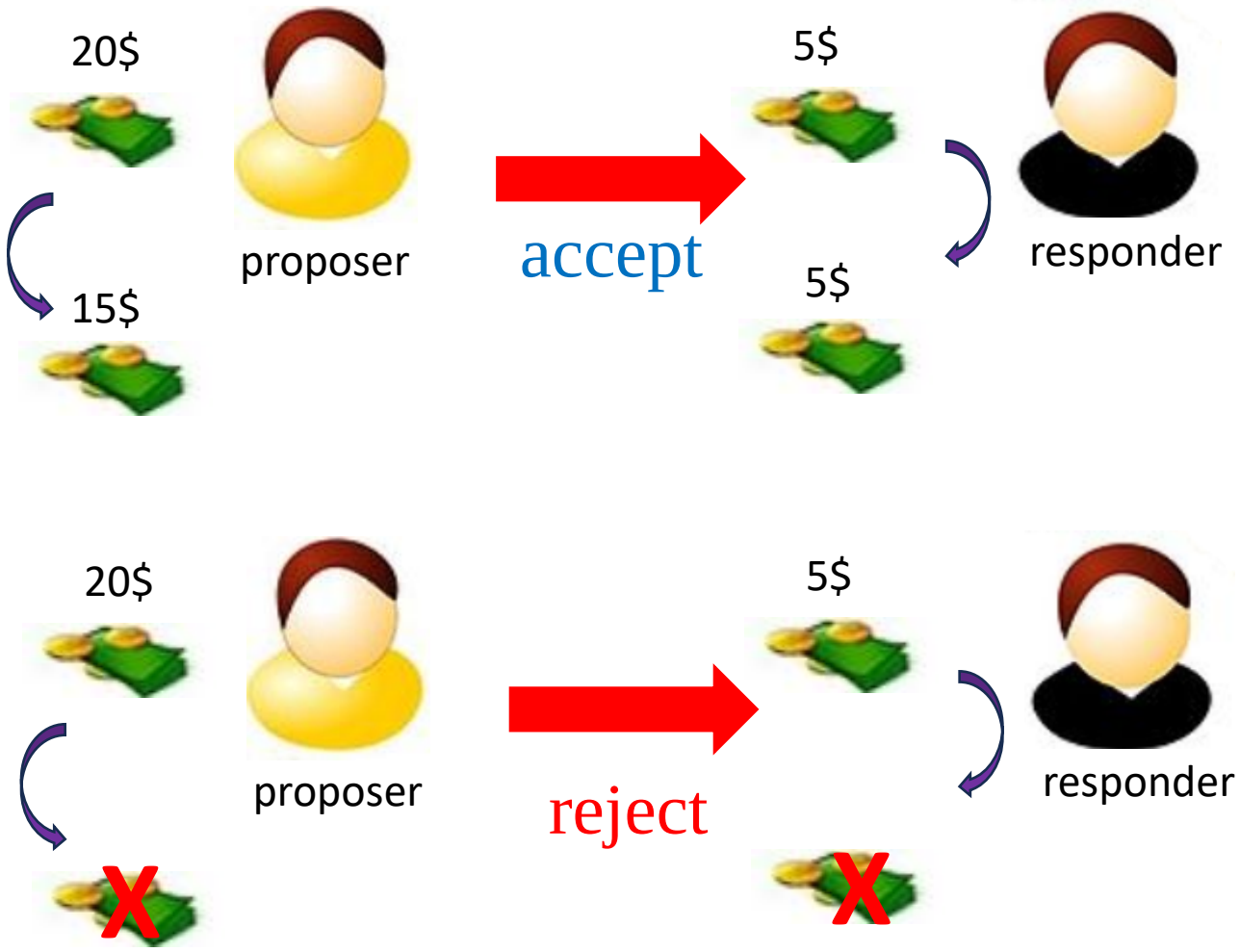
- In ultimatum experiments, two people are randomly and anonymously matched, one as **proposer** and one as **responder**, and told they will play a game exactly one time.
- The proposer is endowed with an amount of money and **suggests** a **division** of that amount between himself and his responder.
- The responder observes the suggestion and then decides whether to accept or reject.
- If the division is accepted, then both earn the amount implied by the proposer's suggestion. If rejected, then both the proposer and responder earn nothing.

Ultimatum Game

Practical example: a **proposer** and a **responder** have to agree on the division of a given amount of money, say $20, according to the following rules:

1) the **proposer** can make exactly one suggestion on how the $20 should be allocated between the two by making an integer offer X to the responder.

2) then the **responders** can either accept or reject X. In case of a rejection, both players earn $0; in case of acceptance, the responder earns X and the proposer earns $20–X

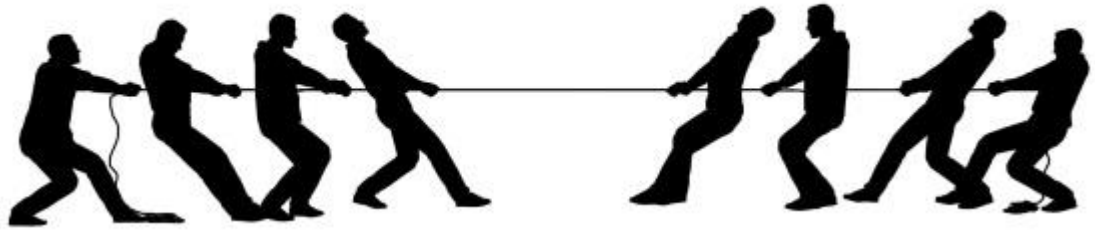


Ultimatum Games

ULTIMATUM GAME illustrates the tension between:

economic self-interest

reciprocity and equity motives



Ultimatum Game

If concerns for **reciprocity and equity motivate him**, he might reject low offers because he views them as insultingly unfair and inequitable

If economic self-interest alone motivates the responder →he will accept even a very low offer, say $1, because $1 is better than $0

proposer

20$

responder

Ultimatum Game: results

proposer

20$

responder

1. The key result of ultimatum experiments is that most proposers offer **between 40% and 50% of the endowed amount (donation amount)**, and that this split is almost always accepted by responders.
2. **Rejection** rates up to 80% have been observed (Camerer et al., 2003) for offers **below 25%** of the available money, and rejection rates increase as the proposal falls to 10% and lower. Strong evidence (Henrich et al., 2001; Camerer et al., 2003) suggests that many people reject low offers in the game, even if stake levels are as high as 3 months' income (Cameron, 1999).
3. A pioneering imaging study (Samfeu et,. 2003) showed that both **the anterior insula** - an important brain area involved in the processing of emotions - and the dorsolateral prefrontal cortex (**DLPFC**) are activated when responders decide whether to accept or reject an **unfair offer**.
4. As discussed by Camerer (2003), ultimatum game results are highly robust to a variety of natural design manipulations (e.g., repetition, stake size, degree of anonymity, and a variety of demographic variables).

Time to think, time to produce, time to discuss!

- Groups

- Open pubmed

- Search for **RECENT** articles:
  - Prisoner Dilemma and Decision making
  - Ultimatum game and Decision making

We cannot study a single brain and predict an individual's behaviour

Conclusion 1: we need to study social behaviour in order to understand decision making

Conclusion 2: we need to study behaviour using different methods

Conclusion 1: Study social behaviours

- Crucial to study economies:
    - individual level
    - society as a whole (Krugman & Wells, 2004)
- Study how human beings coordinate their wants and desire, given the decision-making mechanisms, social customs and political realities of the society (Colander, 2006)

Definition of economics

- Taking together different definitions…

Economics is a **social** science concerned with the production, distribution and consumption of goods and services. It studies how individuals, businesses, governments, and nations make choices on allocating resources to satisfy their wants and needs, trying to determine how these groups should organize and coordinate efforts to achieve maximum output.

Definition of economics

Economics can generally be spitted into 2 subfields:

Macroeconomics

- It is related to the behaviour of aggregate economy (nations, world economy)

Microeconomics

- It focuses on individual consumers and businesses

INTERESTED IN DECISION MAKING:

Individuals' decision making

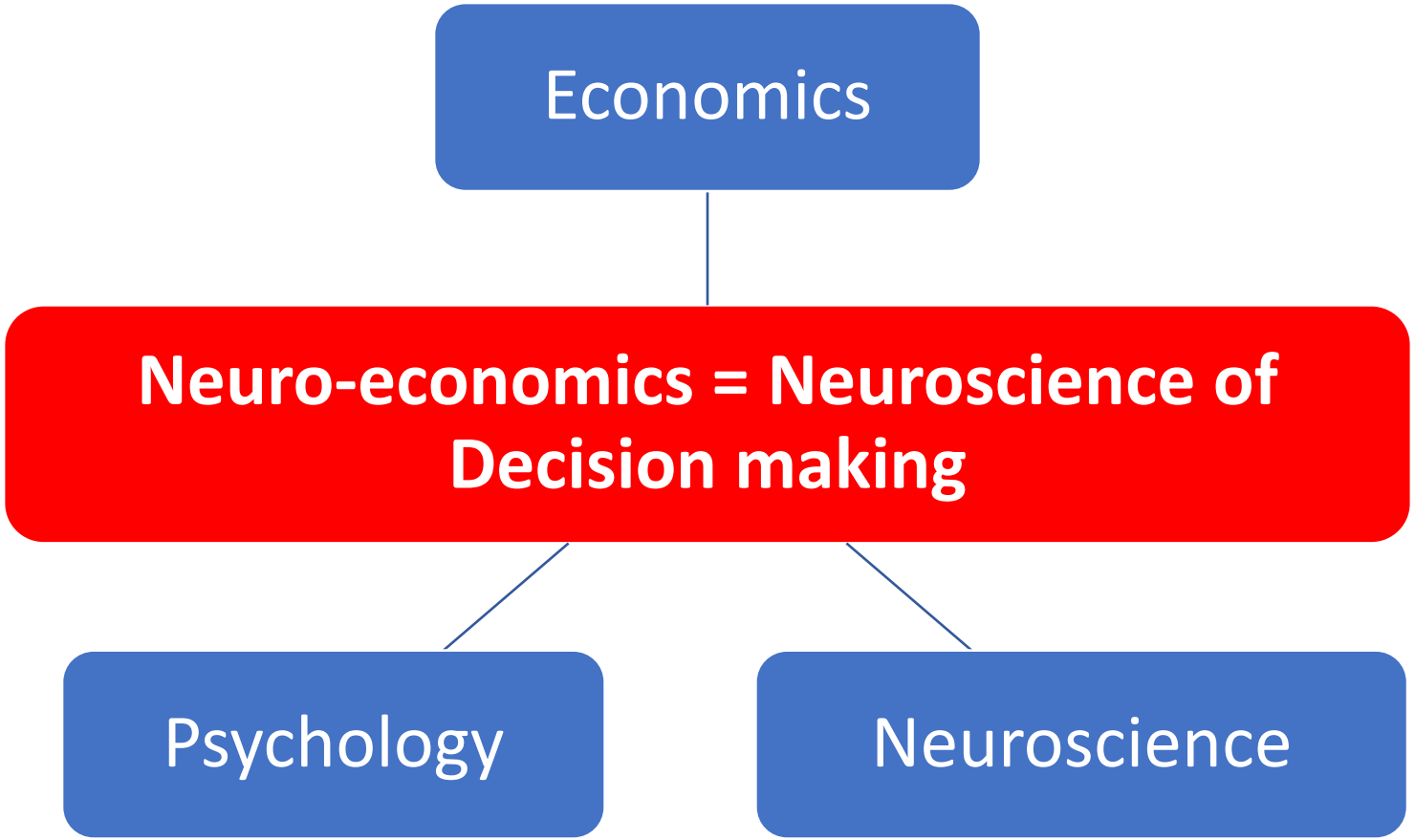
Conclusion 2: We need neuroscience

Economics

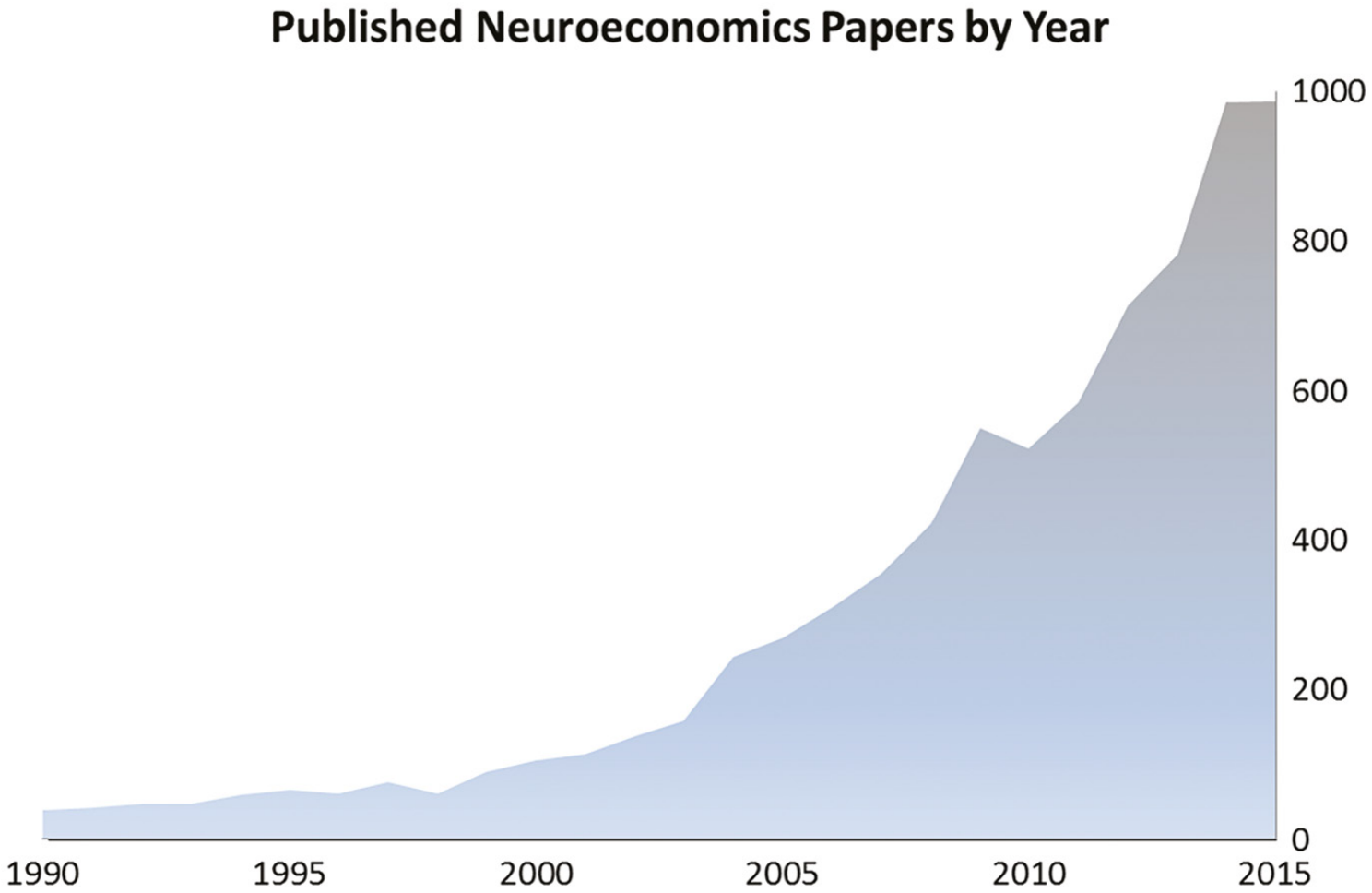
Psychology

Neuroscience

Neuroeconomics as interdisciplinary field



Studies on decision making



The rise of neuroeconomics has been strongly associated with the rapid development of non-invasive neuroimaging techniques for human research and single-cell recordings in non-human primates

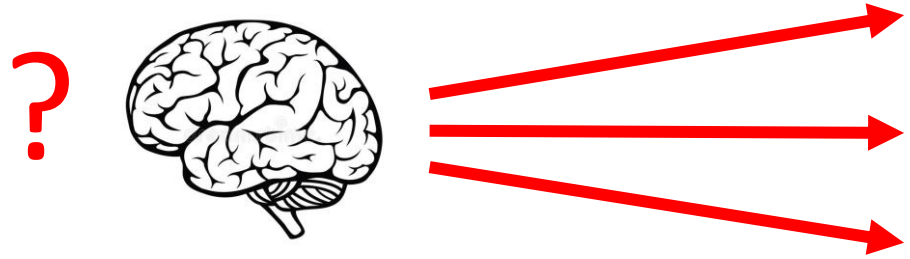
Decision making

- Paul Glimcher: godfather of neuroeconomics.
- Experimental approach to combine economics and neuroscience
- In 2004, he founded the Center for Neuroeconomics at New York University, one of the first research centers ever dedicated to the field.
- In March 2014 the Center for Neuroeconomics became the Institute for the **Study of Decision Making**

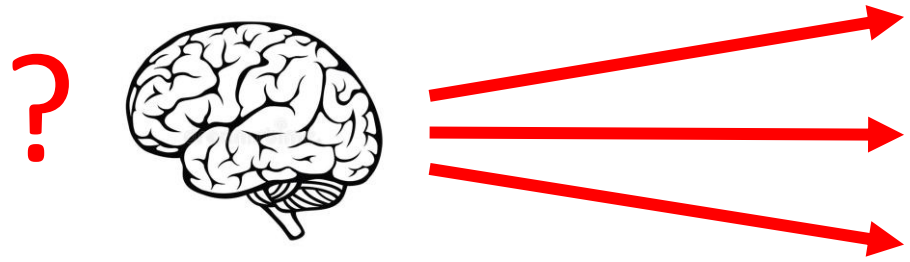
Paul Glimcher

Individual decision making

- E.g. decision making of consumers

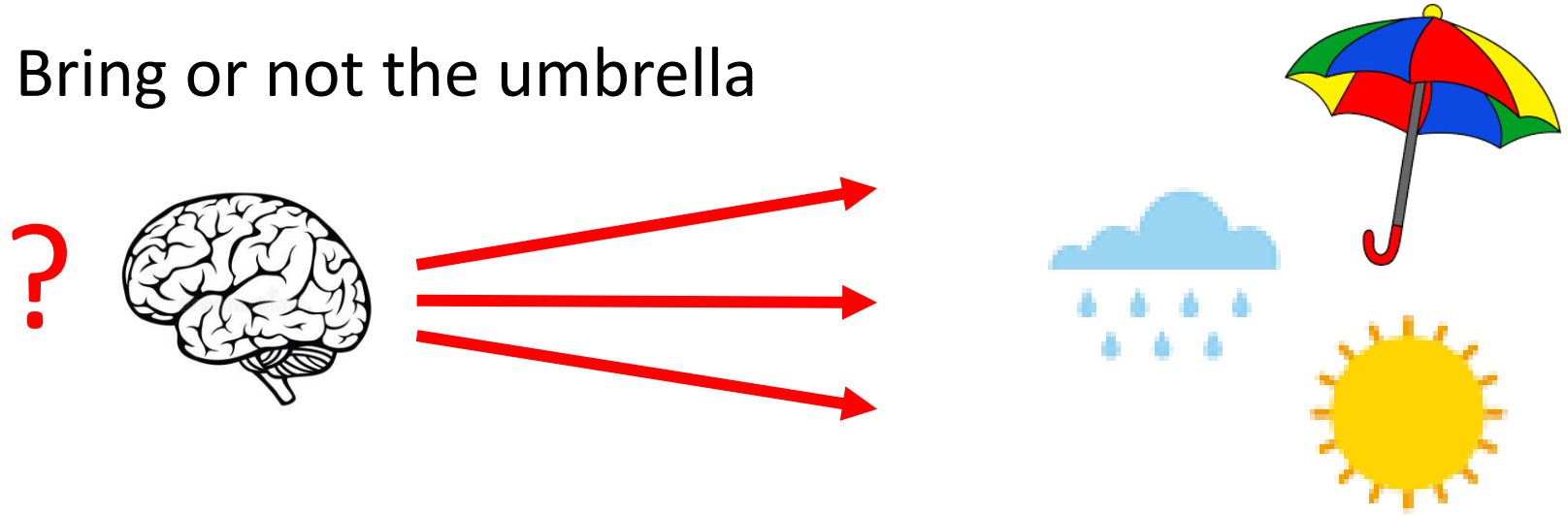


- E.g. decision making of financial decisions

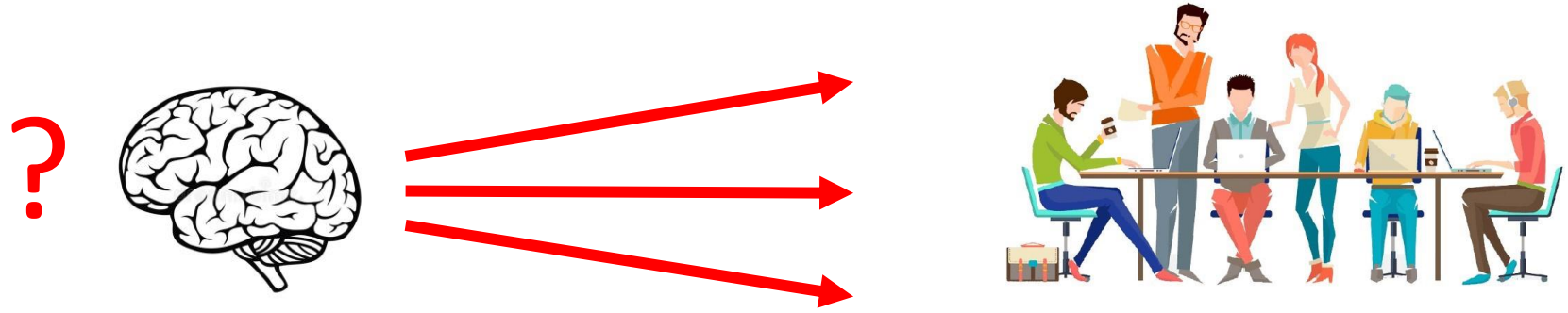


Individual decision making

- E.g. Bring or not the umbrella

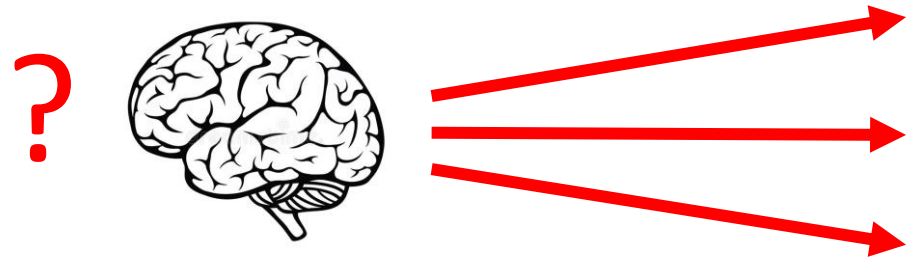


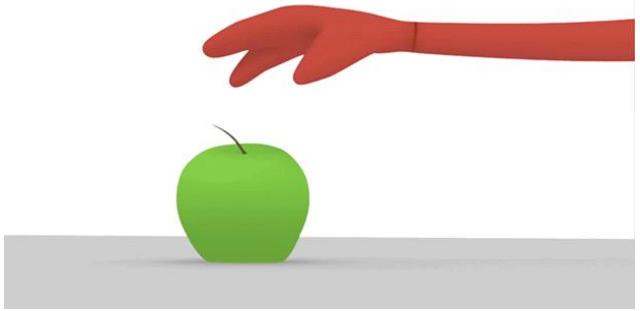
- E.g. Hire an employee



Individual decision making

- E.g. move an arm





- E.g. move a paralyzed arm

Published in final edited form as:
Lancet. 2017 May 06; 389(10081): 1821–1830. doi:10.1016/S0140-6736(17)30601-3.

Restoration of reaching and grasping in a person with tetraplegia through brain-controlled muscle stimulation: a proof-of-concept demonstration

Abidemi Bolu Ajiboye, PhD[1,2,6,†,*], **Francis R. Willett**[1,2,6,*], **Daniel R. Young**[1,2,6], **William D. Memberg, MS**[1,2,6], **Brian A. Murphy, PhD**[1,2,6], **Jonathan P. Miller, MD**[2,4,6], **Benjamin L. Walter, MD**[2,3,6], **Jennifer A. Sweet, MD**[2,4,6], **Harry A. Hoyen, MD**[5,6], **Michael W. Keith, MD**[5,6], , **PhD**[7,8,9,10], **John P. Donoghue,** obert F. Kirsch, PhD[1,2,4,6,§]

PLOS ONE

RESEARCH ARTICLE

Cortical control of a tablet computer by people with paralysis

Paul Nuyujukian[1,2,3,4,5,6☯], **Jose Albites Sanabria**[7,8☯], **Jad Saab**[7,8,9☯], **Chethan Pandarinath**[1,2,10,11], **Beata Jarosiewicz**[1,2,8,12], **Christine H. Blabe**[1], **Brian Franco**[13], **Stephen T. Mernoff**[9,14], **Emad N. Eskandar**[15,16], **John D. Simeral**[7,8,9,13], **Leigh R. Hochberg**[7,8,9,13,17‡], **Krishna V. Shenoy**[2,3,4,5,6,18,19‡], **Jaimie M. Henderson**[2,4,5‡*]

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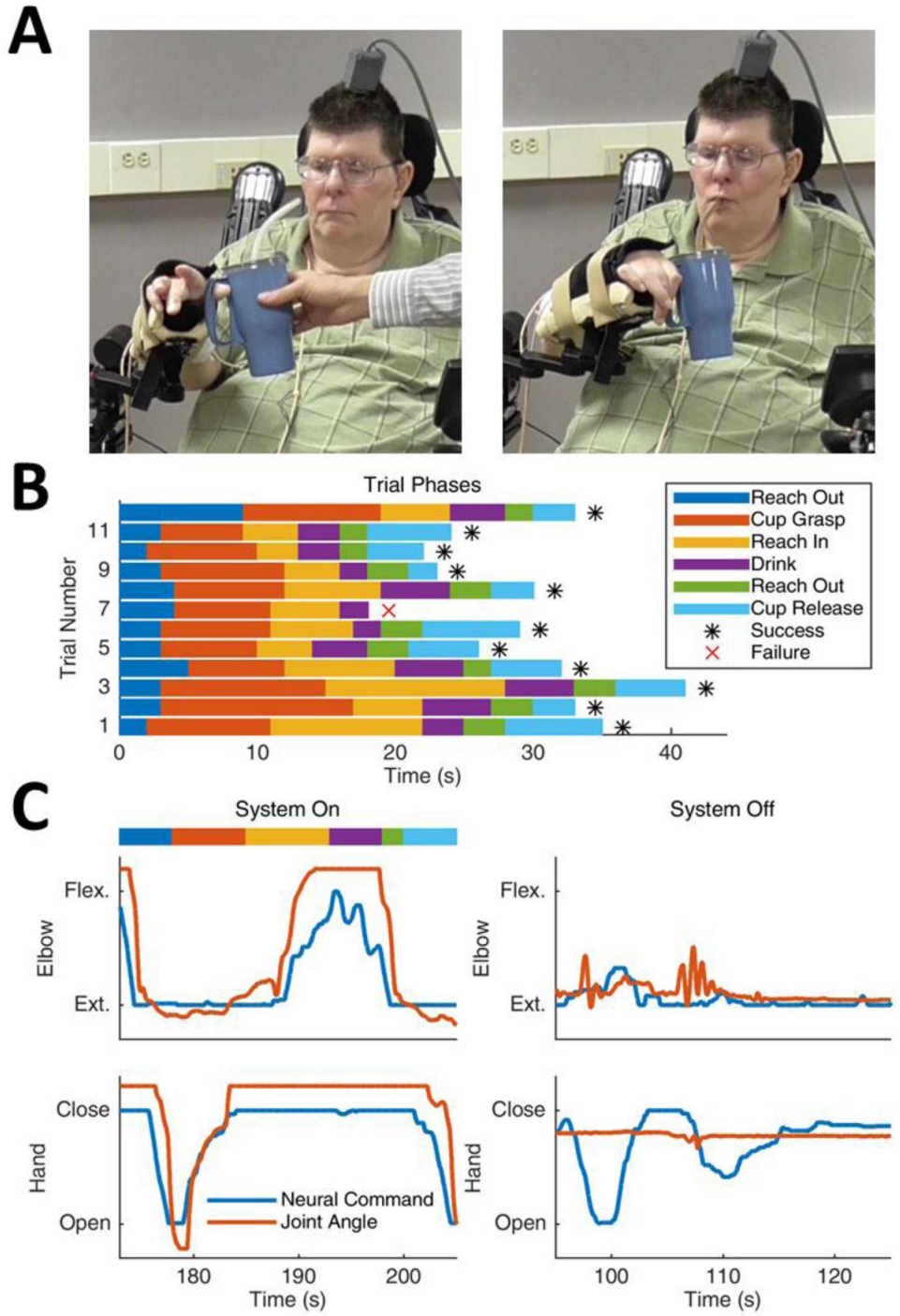
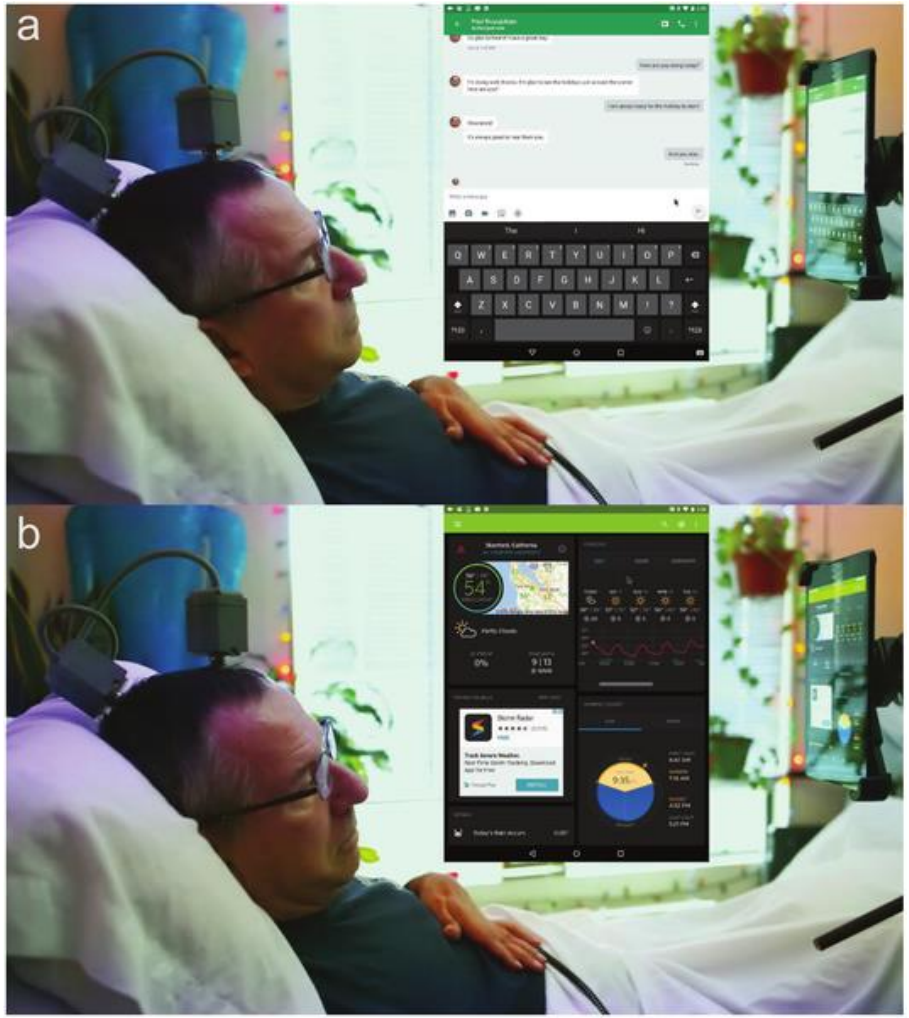
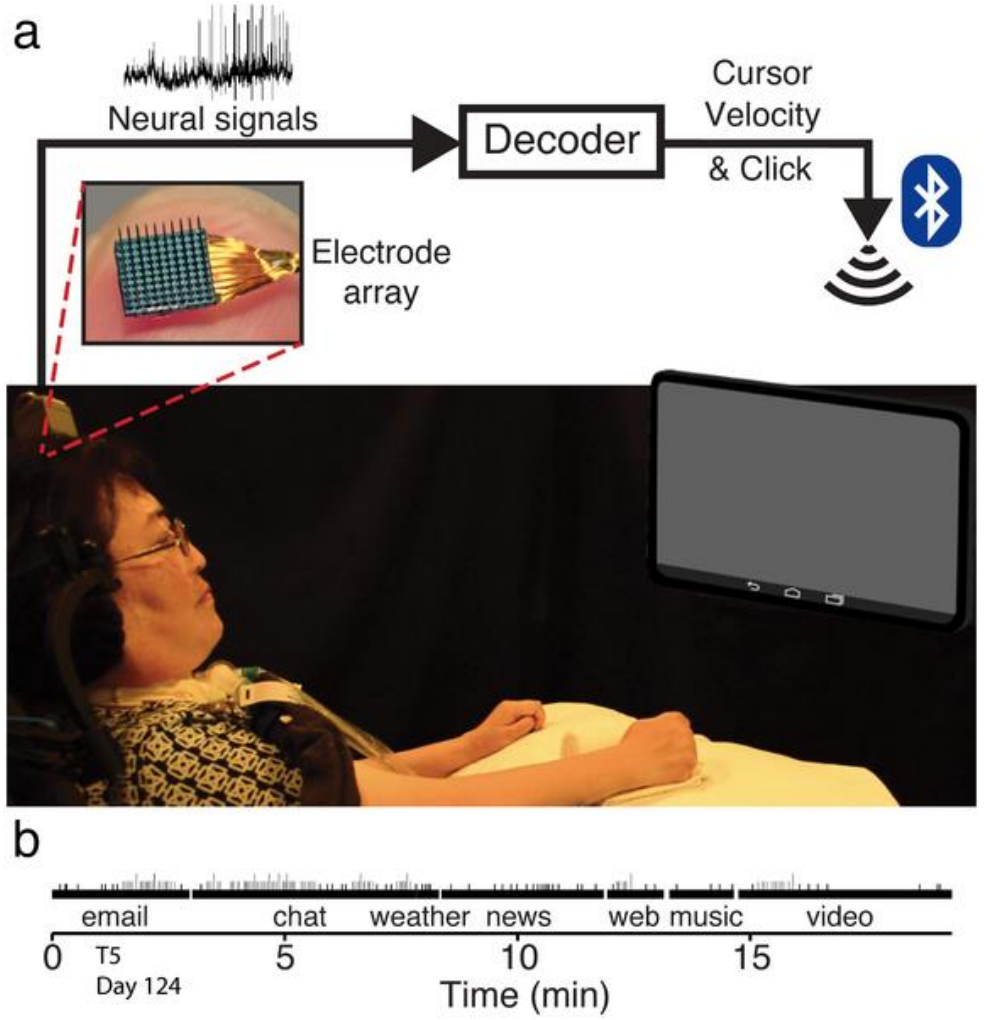
- An artificial arm directly connected to the brain.
- Patient's decisions can be "detected" using implanted electrodes
- Patient can feed himself







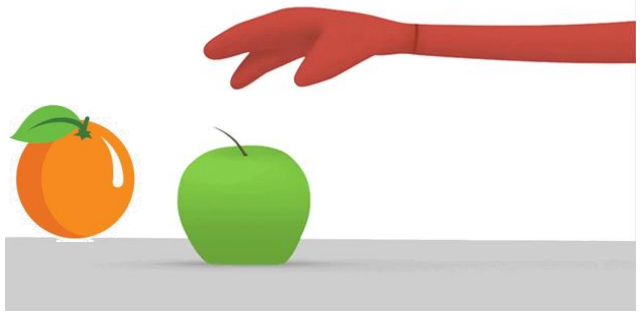
Nuyujukian P, Albites Sanabria J, Saab J, Pandarinath C, Jarosiewicz B, et al. (2018) Cortical control of a tablet computer by people with paralysis.
PLOS ONE 13(11): e0204566. https://doi.org/10.1371/journal.pone.0204566
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0204566

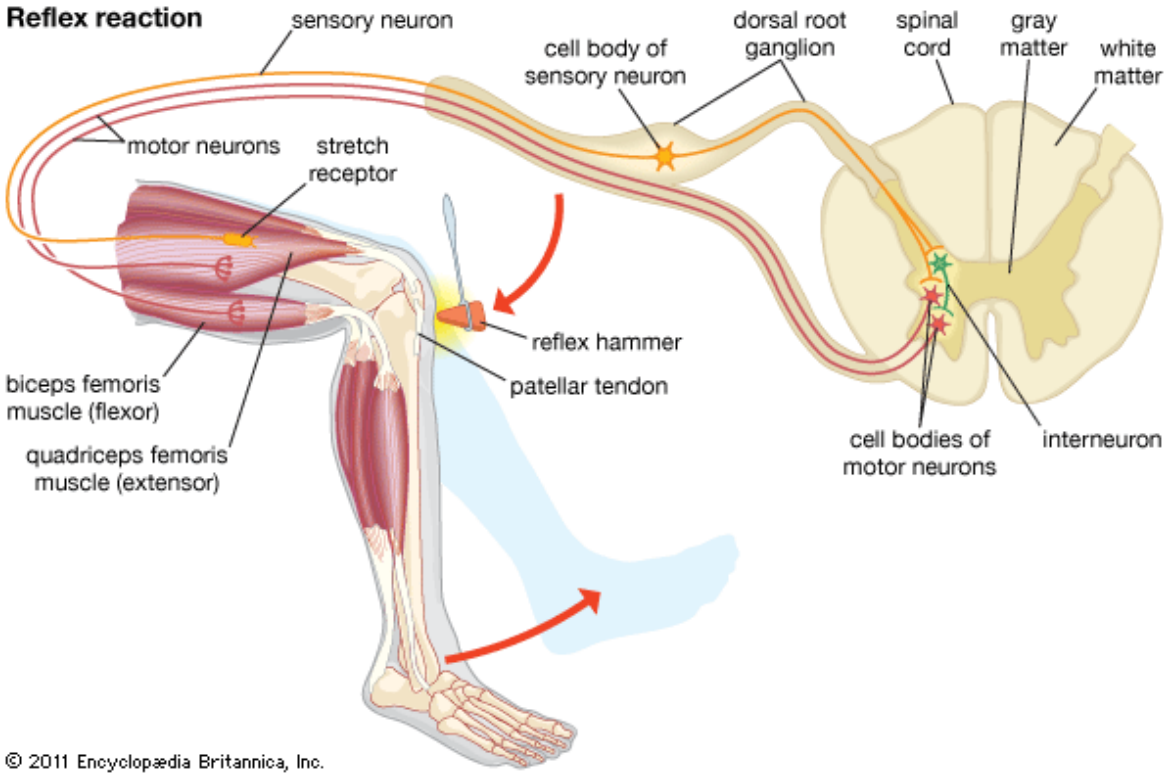
Conditions to make decisions

1. We need options to choose

No options

options





Conditions to make decisions

2. We decide according to some “rational” or “non-rational” purpose
   → it means that we don’t choose in a random way

3. Our choices are goal-directed

→ decision making theory investigates goal directed behaviors when options are presented

Decision making theories

- **NORMATIVE** → theory about how decisions should be made

- **DESCRIPTIVE** → theory about how decisions are actually made

Neuroeconomic is a **descriptive** theory

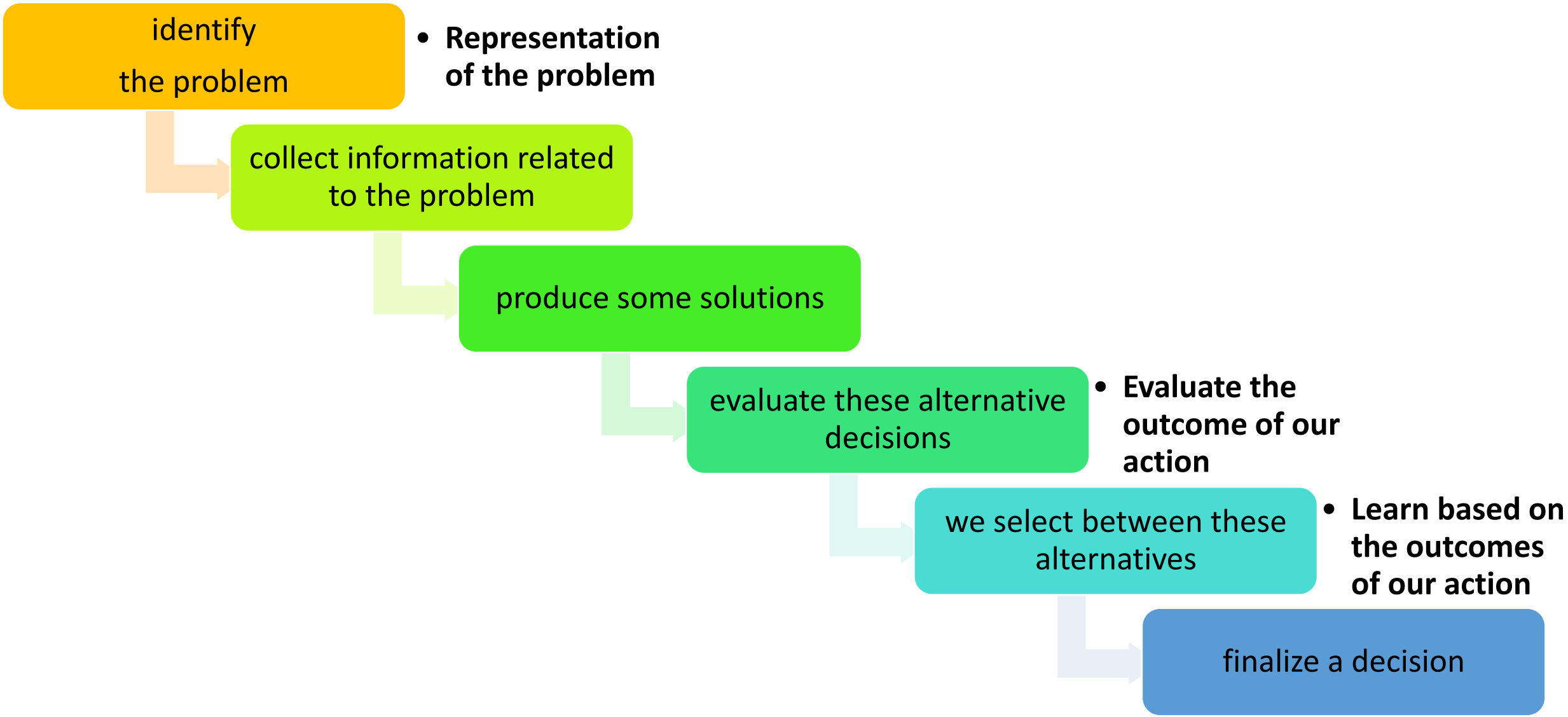
Normative Decision making theories

- **Normative decision theory** is concerned with identification of optimal **decisions** where optimality is often determined by considering an ideal **decision maker** who is able to calculate with perfect accuracy and is in some sense fully rational.

Descriptive Decision making theories

- In contrast, **positive or descriptive decision theory** is concerned with describing observed behaviors often under the assumption that the decision-making agents are behaving under **some consistent rules**.

Stages of decision process



Summary

- Introduction: A Brief History of Neuroeconomics
- **Methods used to study decision making**
- Low level decision making
- High level decision making

Summary

- Methods
  1. Lesions
  2. Electrical stimulation
  3. TMS
  4. Single-cell recordings
  5. EEG and MEG
  6. fMRI

Approaches to study the brain

Lesions

Electrical stimulation

TMS

Single-cell recordings

EEG and MEG

fMRI

there is no one ideal approach (pros/cons… limits)

Static

Dynamic

Temporal resolution

Spatial resolution

Static vs Dynamic

- Static: these methods allow us to visualize the **STRUCTURE** of our SNC
  - Radiography
  - CAT (Computed axial tomography)
  - MRI

- Dynamic: these methods allow us to study brain **FUNCTIONS**
  - Single neuron recordings
  - EEG
  - ERP
  - PET
  - fMRI

Temporal resolution vs spatial resolution

- Temporal: how can we differentiate different stages (time) of decision making processes

- Spatial: how can we differentiate the activation of different (spatial) neuronal populations involved into the decision making process

1. Lesions

- Lesions can trigger some changes in our behavior and also can change our decision making processes
- A lesion is a tissue damage that can occur for a trauma or a disease
- Neuropsychology → the study of lesions in humans and animals (the study of a lesioned/damaged brain in order to know the physiology of a intact brain)
- Famous case of P. Gage and his frontal lesion.

1. Lesions: pros vs cons

PROS

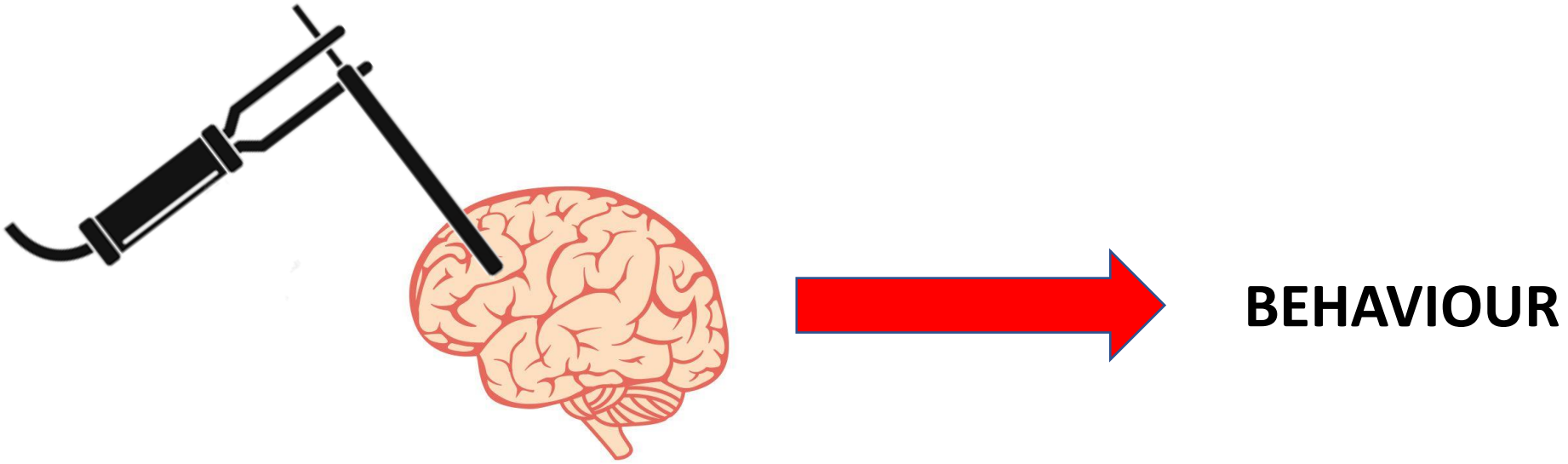
- These studies show causal relationship between the activity of certain regions and decision-making process
- Can produce unique evidences and insights

CONS

- Rare patients (that is a positive for the population!)
- Lesions are usually large and not focal
- Consequences are not reversable and can be compensated by other processes

2. Stimulation of brain regions

- Different studies showed that if we stimulate specific brain regions we can induce specific behaviours



BEHAVIOUR

2. Stimulation: pros vs cons

PROS

- Short term effects
- Can produce unique evidences and insights

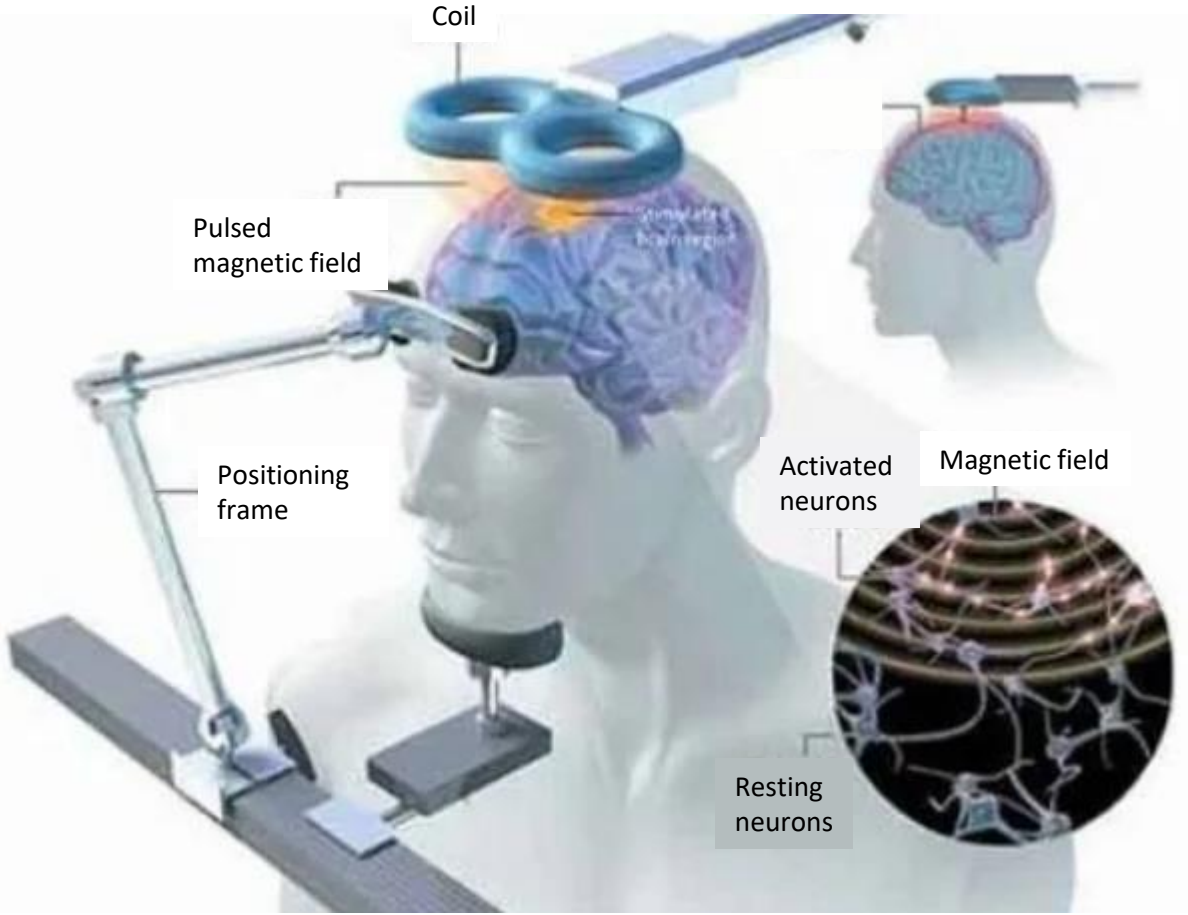
CONS

- Invasive (tissue damage)
- Specially used in animal models
- Stimulations of large and not focal regions

3. TMS (Transcranial Magnetic Stimulation)

A way to stimulate the human brain and without any damage

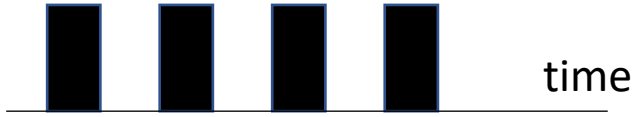
- You apply a coil, consisting of metallic wires, on a specific brain region
- You activate the current
- The coil produces a magnetic field
- Magnetic field propagates into the skull and interferes with the activity of specific neurons populations' (e.g. magnetic field induces current flows that inhibits neuron's activity)

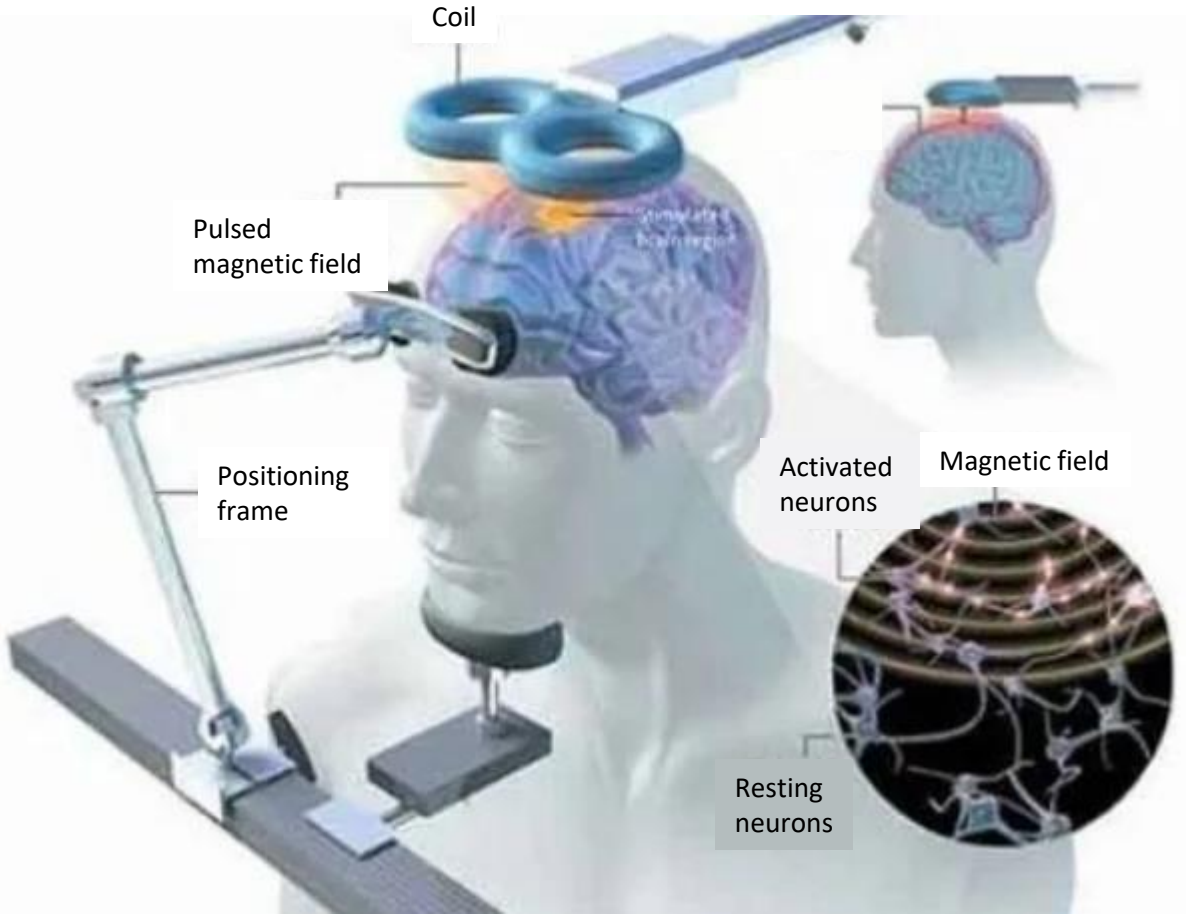


3. TMS (Transcranial Magnetic Stimulation)

Single pulse TMS →single change in the magnetic fields → weak electric change in the brain

Repetitive TMS (rTMS)
→repetitive pulses produce longer changes (10-20 minutes)





3. TMS (Transcranial Magnetic Stimulation)

- Example of TMS: Speech arrest

- https://www.youtube.com/watch?v=FMR_T0mM7Pc

3. TMS : pros vs cons

PROS

- Transient or long term effects
- Shows causal relationship between area and behaviour

CONS

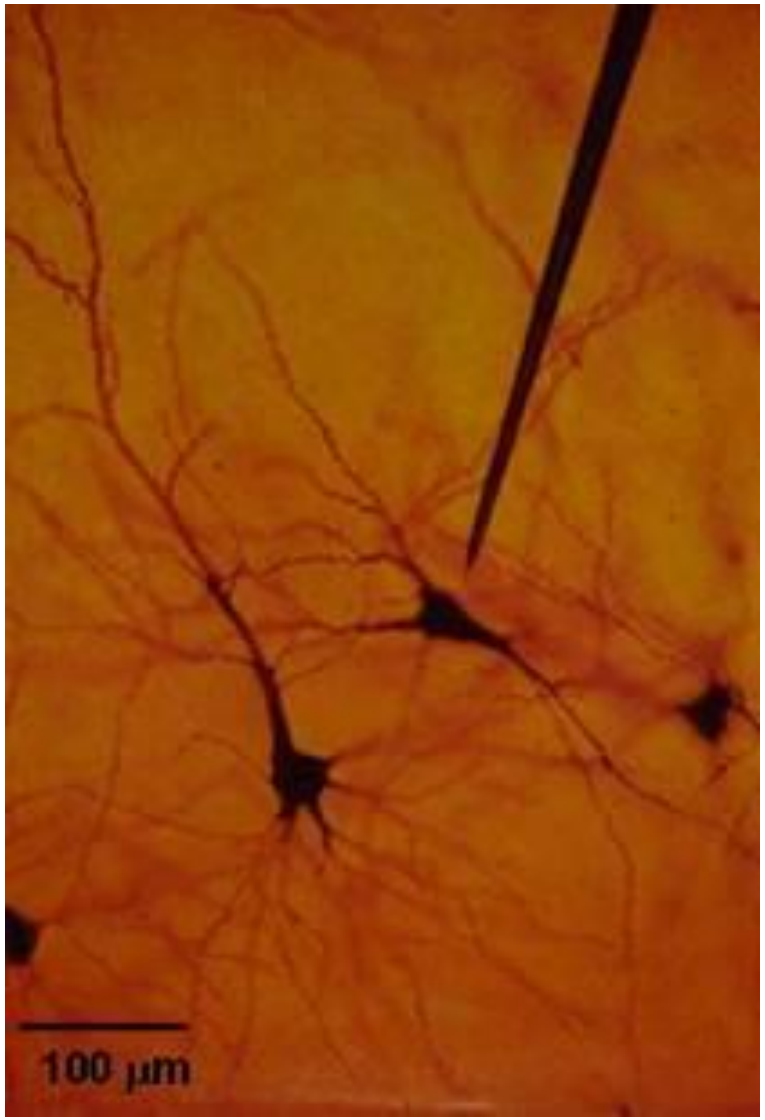
- Focus on cortex and not deep brain TMS stimulation
- There are medical limits for magnetic fields exposure
- Produces loud sounds and muscle contractions
- Mild risk of epileptic seizures

4. Single-cell Recordings

The typical size of a neuron is between 10-50 micrometers

(1um = 0.000001 m)

We can record the activity of one neuron using single cell recording method → put a small electrode inside the neuron or nearby and record the action potentials



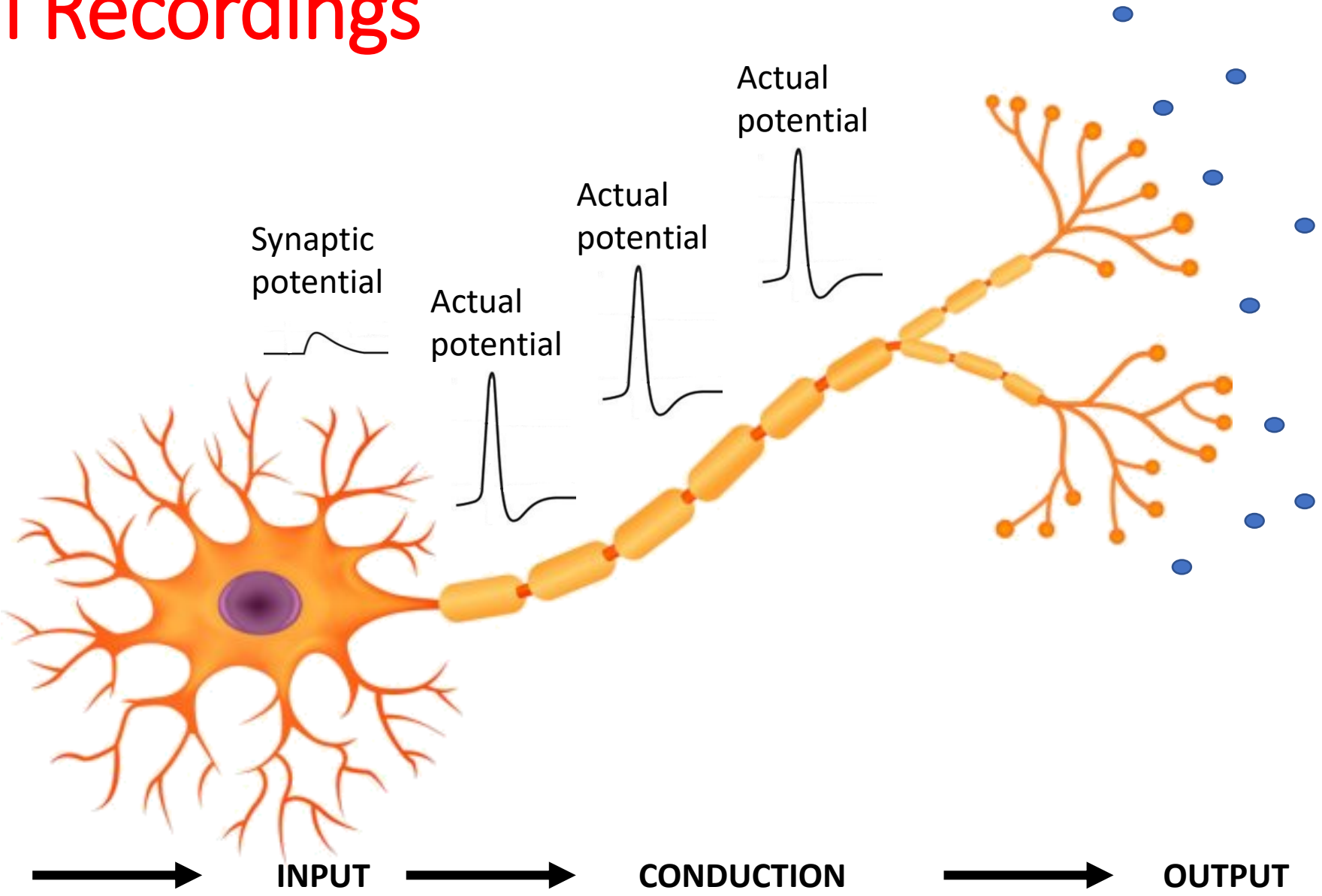
4. Single-cell Recordings

- Input arrives to the dendrite
- Synaptic potentials
- If this activation exceeds a threshold

→ Actual potential is produced

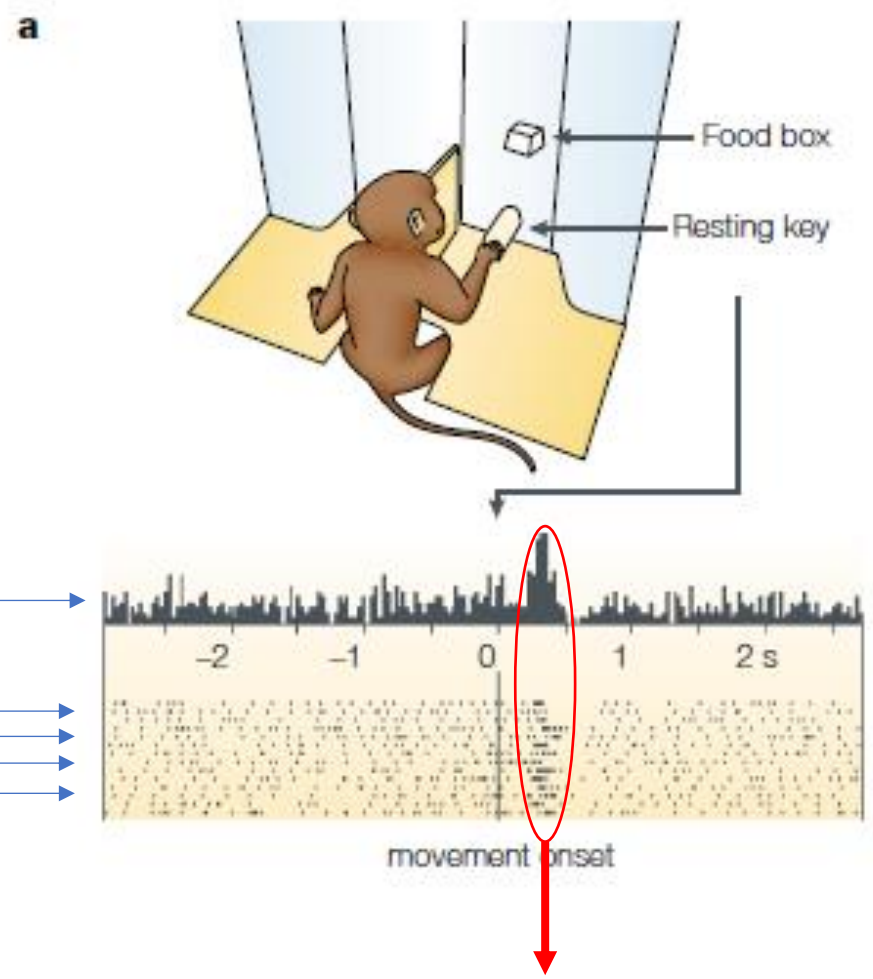
- Actual potential propagates to axon
- Release of neurotrasmitters

How can we study neuron activity during the decision making process?



4. Single-cell Recordings

Grasping food



The monkey has to grab food from a box

Representation of the activity of the neuron:

- dot represents spikes
- line represents trials
- Histogram represent the firing rate (sum of the spikes/s)

The neuron is active when the monkey grab the food (reward)

Schultz et al., 2000

4. Single-cell Recordings: pros vs cons

PROS

- Record the activity of single neurons or few neurons at the same time
- Direct measure of neuronal activity

CONS

- Invasive procedure
- Limited to few neurons
- Unclear information code

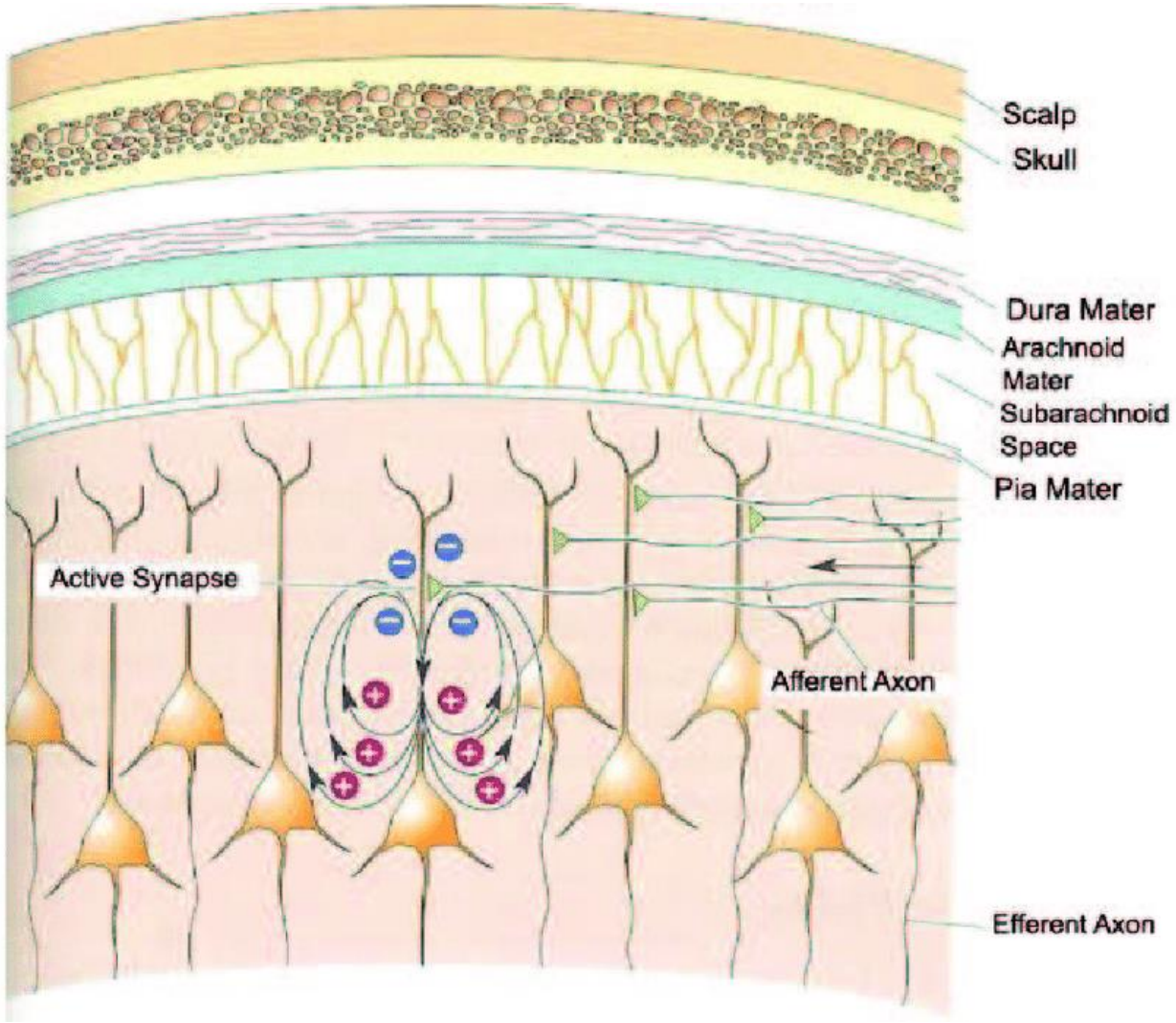
5. EEG and MEG

EEG is a recording of electrical activity produced by neuron's firing

MEG is a recording of the magnetic fields produced by electrical activity in the brain. MEG uses extremely sensitive devices called superconducting quantum interface devices.

5. EEG and MEG

- Neurons are organized structure.
- Populations of neurons can be seen as **dipoles**, negatively charged on the top and positively charged in the middle.
- This difference induces **local electrical fields** that can be recorded by electrodes positioned outside the brain.



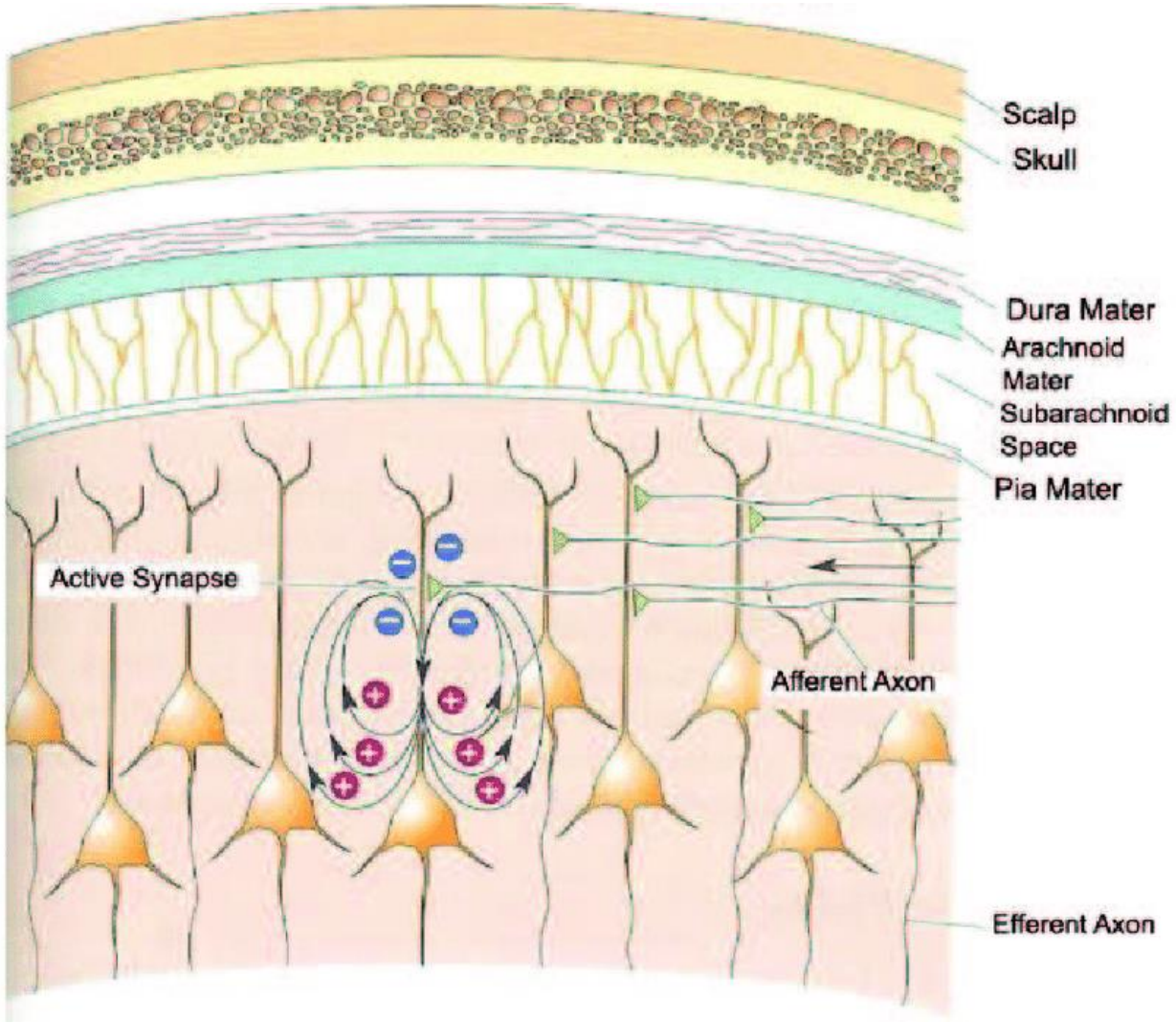
5. EEG and MEG

EEG detects electrical currents

MEG detects magnetic fields

EEG is sensitive to the electrical, local current induced by active populations of neurons.

Local current induces magnetic fields that can be detected by MEG.

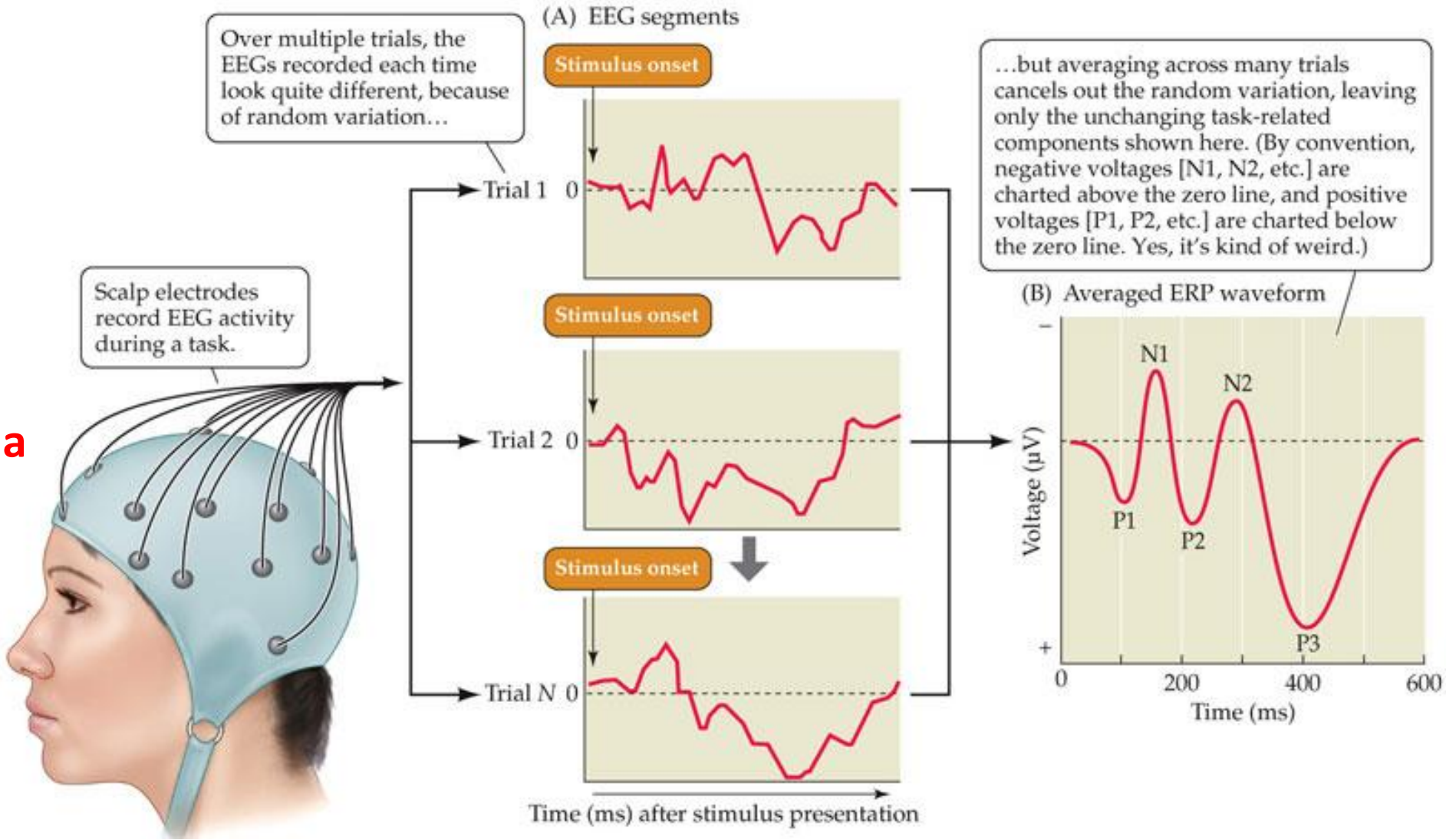


5. EEG and MEG

EEG vs ERPs

- Presentation of stimuli
- Average of trials
- Filter the noise
- **Brain response to a specific stimulus**

→ We can use EEG to investigate decision making processes



5. EEG and MEG: pros vs cons

PROS

- EEG is cheap
- Perfect time resolution

CONS

- MEG is expensive
- Bad spatial resolution
- MEG and EEG reflect post-synaptic potentials

6. fMRI

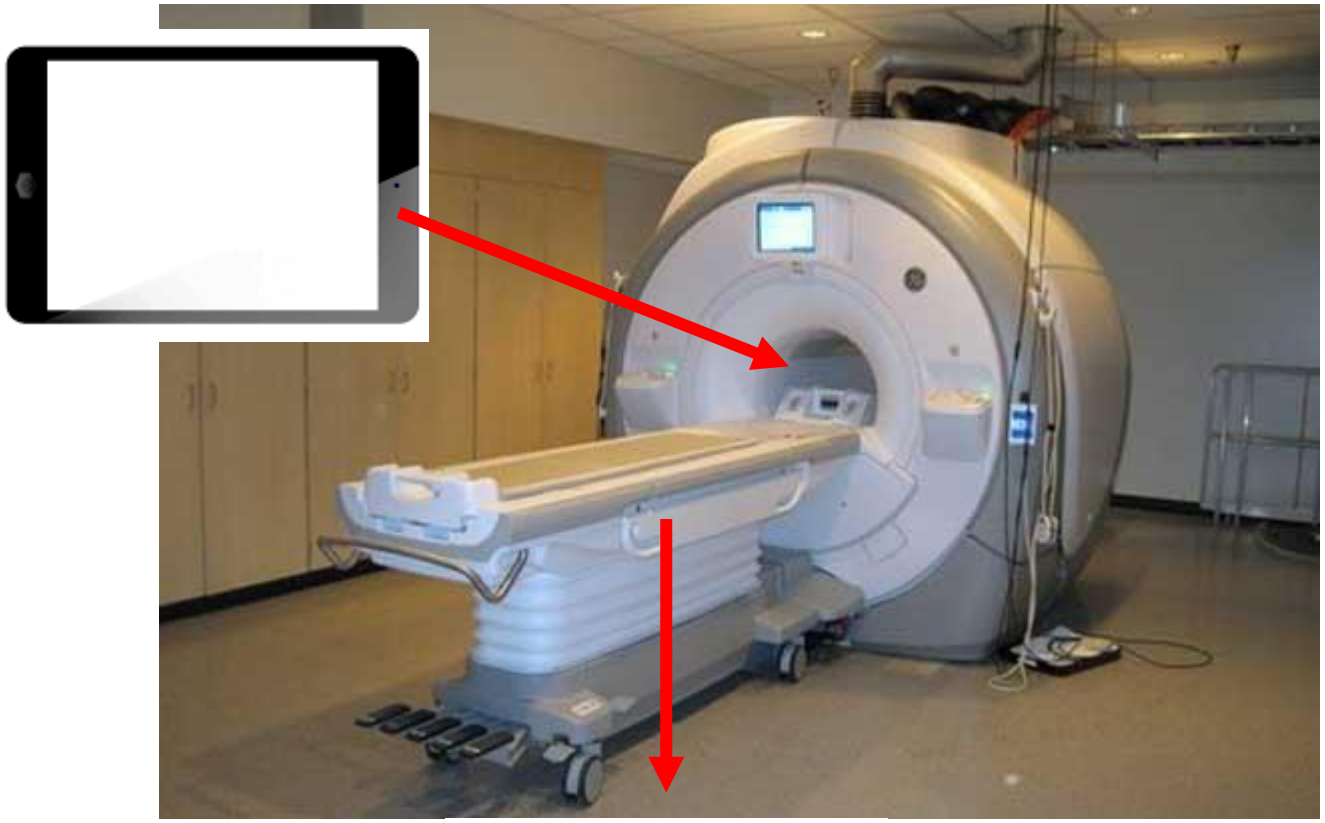
- Measures brain activity by detecting changes associated with blood flow.

- This technique relies on the fact that **cerebral blood flow** and **neuronal activation** are coupled. When an area of the brain is in use, blood flow to that region also increases.

- The primary form of fMRI uses the blood-oxygen-level dependent (**BOLD**) contrast (Ogawa, 1990) → record changing in blood flow (hemodynamic response) related to energy used by the brain cells.

6. fMRI

project
stimuli
inside



devices to record
behavioral responses

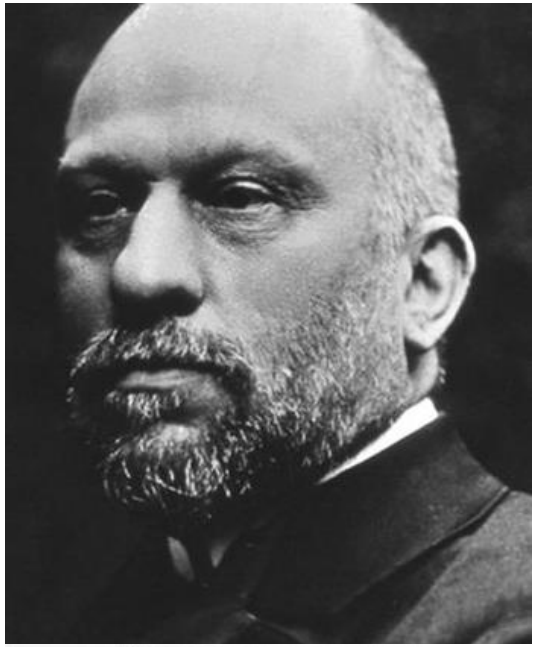
6. fMRI

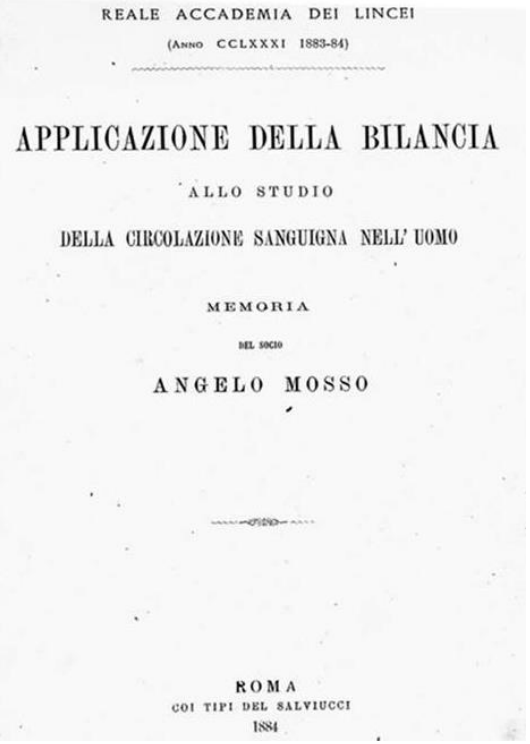
6. fMRI

- The relationship between brain function and blood flow changes was first investigated in 1890 by Charles Smart Roy and Charles Scott Sherrington.

- In the late 1870s, i.e. 10 years before Roy and Sherrington's research, Mosso wrote his previous observations on the hypothesis that an attentional or cognitive task can locally increase cerebral blood flow.

- The fMRI method can be explained by a very interesting and old study conducted by Mosso.




REALE ACCADEMIA DEI LINCEI

(Anno CCLXXXI 1883-84)

APPLICAZIONE DELLA BILANCIA

ALLO STUDIO

DELLA CIRCOLAZIONE SANGUIGNA NELL' UOMO

MEMORIA

DEL SOCIO

ANGELO MOSSO

ROMA

COI TIPI DEL SALVIUCCI

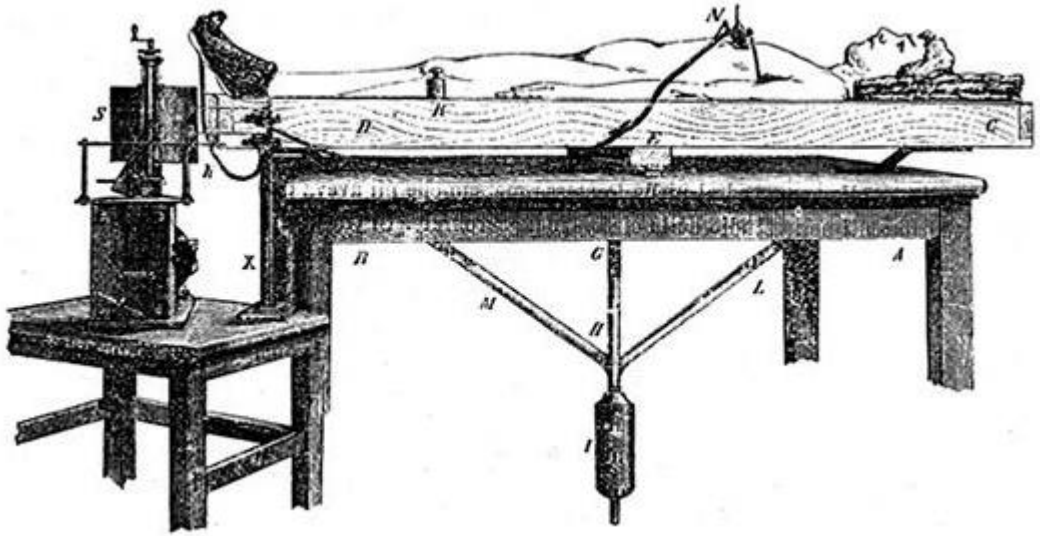
1884

6. fMRI

Mosso developed the '**human circulation balance**'.

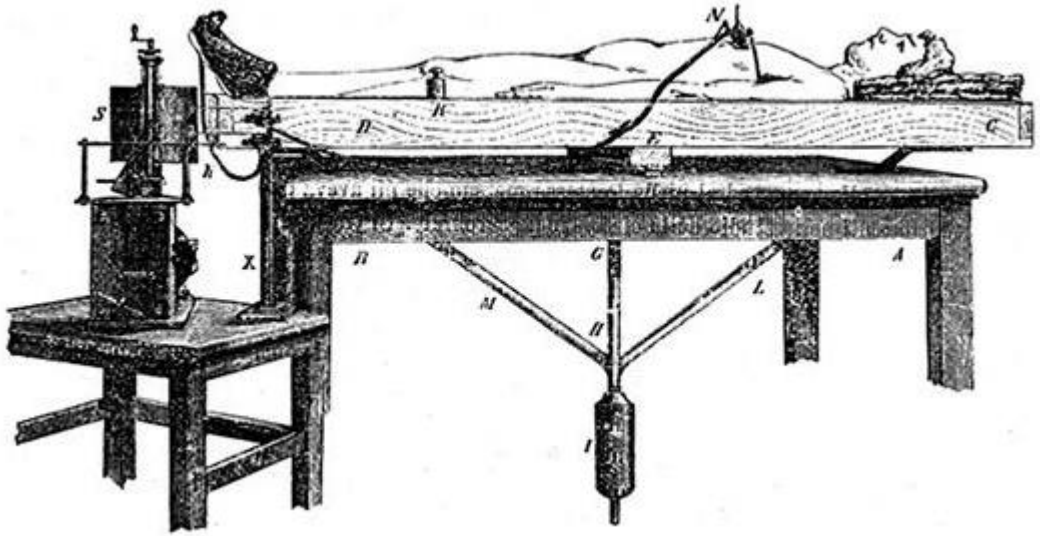
The 'human circulation balance' invented by Mosso consisted of a wooden table lying on a fulcrum. Subjects were first asked to lie down on the balance and not to move. Subsequently, after an initial adaptation phase needed for the blood to redistribute equally within the bodily tissues, the subject was steadily repositioned so as to overlap the barycenter with the central pivot of the fulcrum.

This overlap was partially achieved by careful regulation of balance weights but also, as Mosso showed, by adjustments to the level of water inside a glass bottle positioned on one side of the table



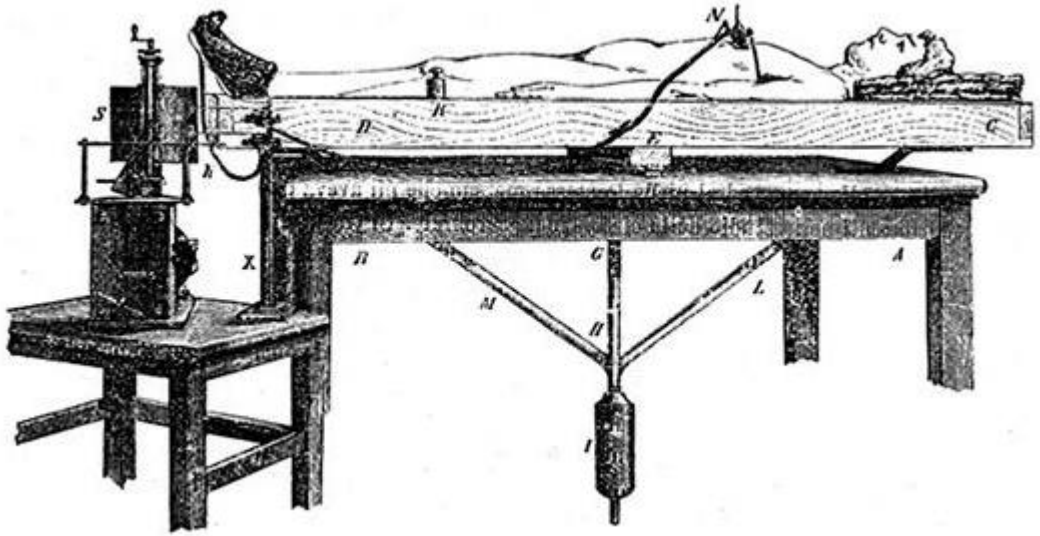
6. fMRI

Once equilibrium was reached, the only observable movement was that induced by breathing during inspiration. Because this might cause a transitory increase in blood flow towards the lower extremities, the wooden table was linked to a heavy counterweight to dampen respiratory fluctuations

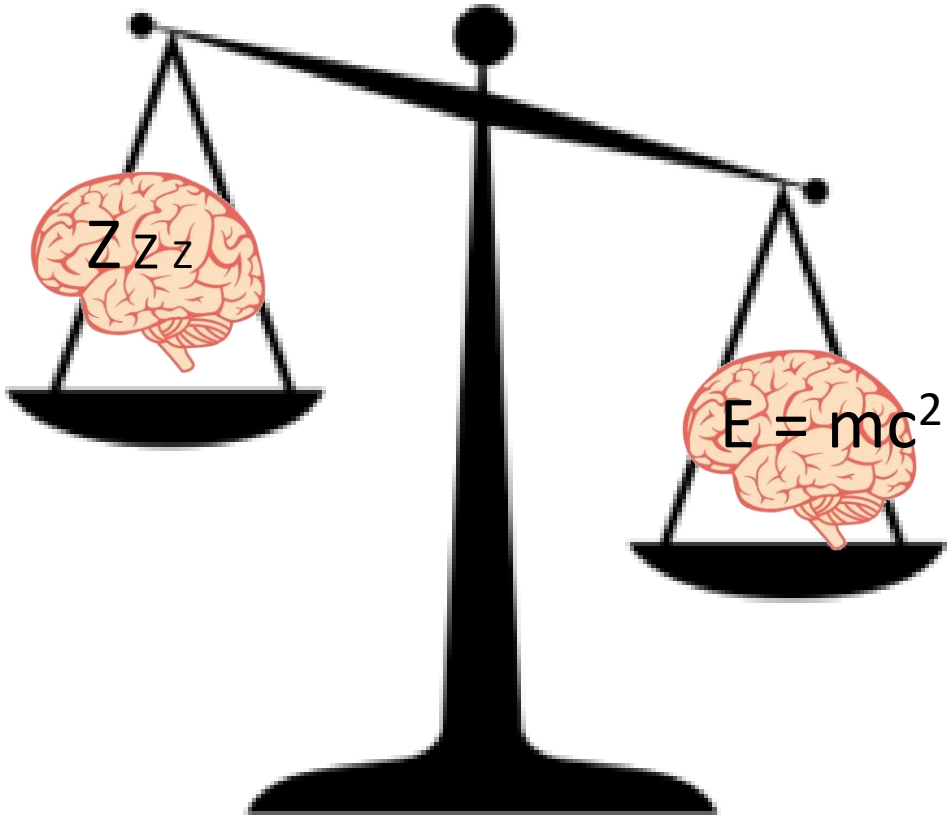


6. fMRI

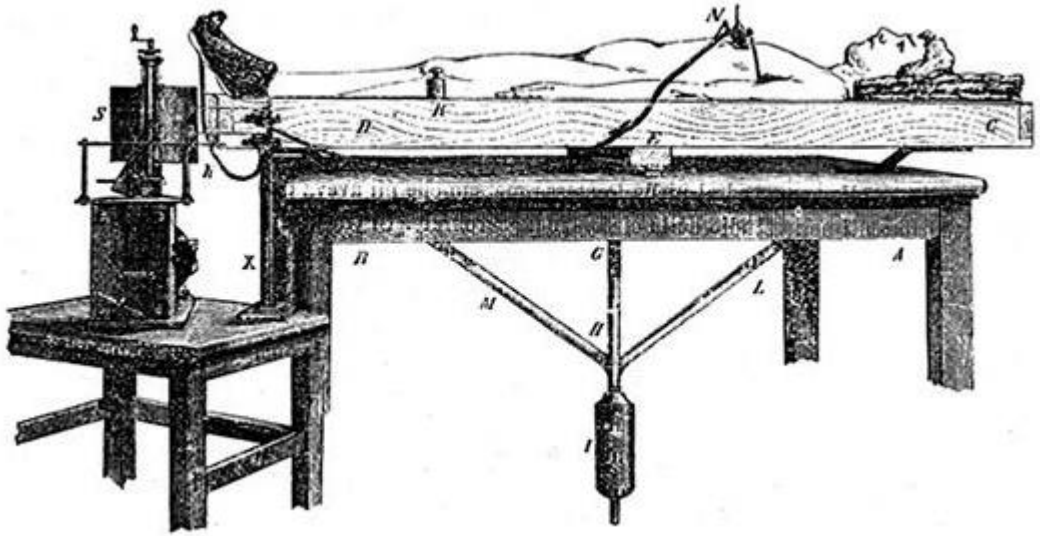
After the resting period, Mosso sequentially exposed the subjects to a wide range of stimuli of increasing cognitive complexity, such as a page from a newspaper, from a novel, from a manual of mathematics or philosophy, or a page written in abstruse language (Mosso, 1935). He reported that the increasing complexity of the stimulus modulated cerebral blood activity: the balance tilted faster towards the head side when the subject was reading a page written in abstruse language or belonging to a manual than it did when the subject was reading a newspaper or a novel



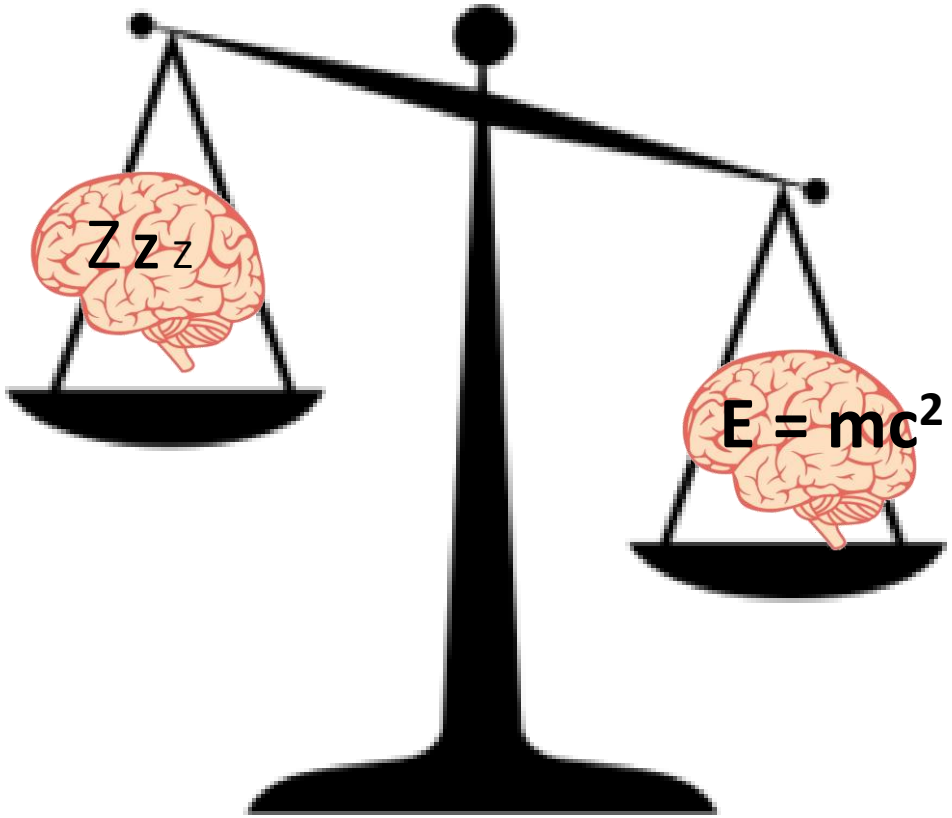
6. fMRI



Basically when we make some complex mental activity, our brain is activated, so neurons, need more energy, that is more oxygen.
This triggers an increase of blood flow to the brain.
This changes the weight of the brain.



6. fMRI



This is the basic of the fMRI method.

The blood vessels of our brain carry O2 to neurons. When neurons are active (e.g. during a mental activity) specific brain regions require hemoglobin, that carries O2.
Hemoglobin changes the magnetic properties of brain tissues and these changes can be detected by a scanner. Thus, the scanner detect the BOLD signal.

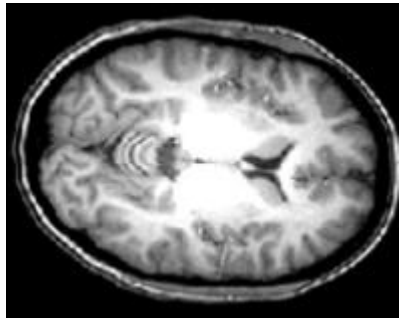
6. fMRI

So there are two major types of MRI:

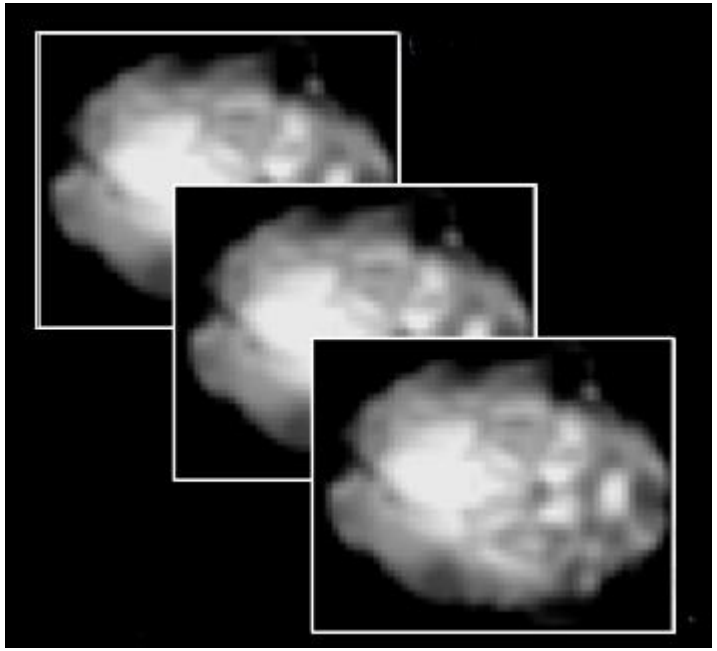
STRUCTURAL: collects structural 3D atlas of the brain

FUNCTIONAL (fMRI): collects the activations of different brain areas during specific tasks (e.g. record the brain activity during the decision making process).

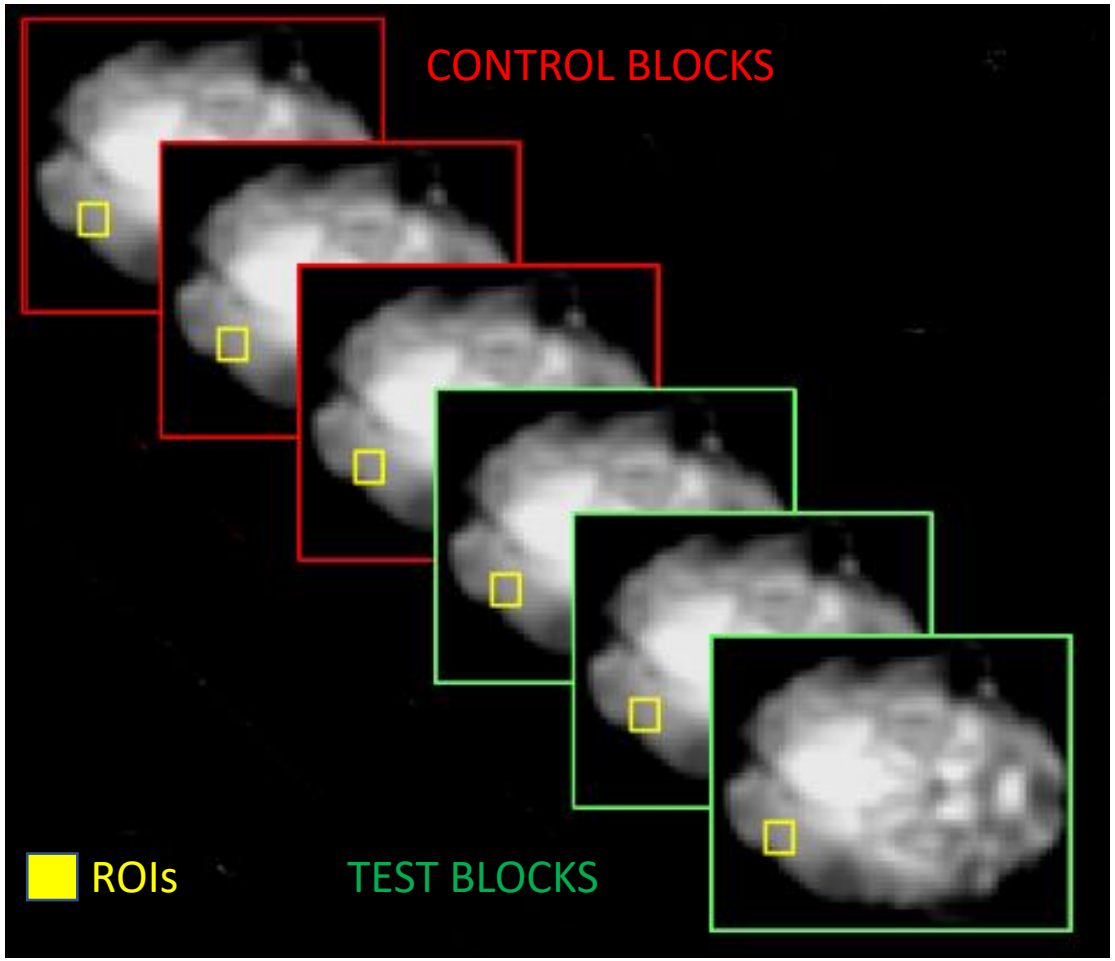
MRI (high resolution, 1mm)



fMRI (low resolution, 3mm)



6. fMRI



Statistical map superimposed on structural MRI image

significant change in the activity of the brain region triggered by the certain task

Higher O2 (local blood flow) → larger MR signal

6. fMRI : pros vs cons

PROS

- Noninvasive
- Good 3D resolution

CONS

- Indirect measure of brain activity (BOLD)
- Produce acoustic noise
- Expensive
- Bad temporal resolution